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THE NUTRITIONAL VALUE OF BLACK SOLDIER FLYMAGGOT MEDIUM ENRICHED DOMESTIC FOOD WASTE FOR ORGANIC SOIL

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ABSTRACT

Green economy is a concern in the world of agriculture through environmentally sound cultivation techniques. One of the biggest environmental issues in the living economy is wasted food waste. A reliable organic decomposer is the maggot black soldier fly. This study aims to provide answers related to the media potential of BSF maggots enriched with home food waste in terms of nutrition. A total of 3 groups of BSF maggot media formulas consisting of A (75:25) group, B (50:50) group and C (25:75 group). The mixture in the media includes wheat bran and food waste The media is then given a fly attractant so that BSF will lay eggs there. The media is waited for 2 months and then observed again after 1 month of cultivation and the media is taken to measure nutrient levels including protein, carbohydrate, lipid, water and ash levels through proximate tests. The data was statistically analysed One Way ANOVA followed by Tukey's test with $p<0.05$. The results showed that BSF maggots were easier to grow in formula B (50:50) than the other 2 groups. The nutritional value of the media with formula B (50:50) was significantly better than the other 2 groups. This study concluded that the 50:50 formula between wheat bran and food waste is the best formula for maggot growth with high media nutrients. This media can be used as organic soil to support agriculture in the green economy era.

KEYWORDS:

BSF, food waste, nutrition, organic, soil.

Introduction

The global issue of food waste is a significant concern with far-reaching implications for resource utilization and environmental impact. Parfitt et al. (2010) highlight the review of food waste within the global food supply chain, emphasizing the potential challenges in feeding a population of nine billion by 2050. Furthermore, You et al. (2022)underscore the substantial carbon footprint associated with food waste, with 88 million tonnes of food waste generated annually in the European Union alone, equivalent to 170 million tonnes of CO2. These references collectively emphasize the scale and impact of food waste on global resources and the environment.

The contribution of households to food waste is a significant concern globally, with substantial implications for resource utilization and environmental impact. In the UK, households contribute the largest share of food waste, accounting for 8.3 million tonnes per year, costing consumers £12 billion and contributing 3% of UK greenhouse gas emissions (Quested et al., 2011). Similarly, in the UK, households account for 6.7 million tonnes of edible food, representing 33% of all food purchased(Grainger et al., 2018). Moreover, in Denmark, unavoidable food waste amounts to 80±6kg per household per year, and avoidable food waste is 103±9kg per household per year(Edjabou et al., 2016).

The use of black soldier fly (Hermetiaillucens) larvae for food waste decomposition has gained attention due to their voracious feeding behavior and ability to convert organic material into valuable resources. Wang and Shelomi (2017) highlight the extensive range of organic materials that black soldier fly (BSF) larvae can feed on, including food waste, manure, rice straw, and distillers' grains. This underscores the potential of these larvae for waste management purposes. Additionally, Diener et al. (2009)emphasize the potential use of black soldier fly larvae in engineered systems to reduce organic waste, particularly in low- and middle-income countries, further supporting their role in waste management.

Furthermore, Humairo and Aisah (2022)present black soldier fly larvae as an alternative for biological waste decomposition, noting their ability to convert waste into protein and fat while reducing waste mass by 50% to 60%. This highlights the potential of black soldier fly larvae as a solution for waste pollution. Moreover, Gunawan (2022) emphasize the potential of black soldier fly maggots to address environmental problems related to waste volume, odors, and greenhouse gas emissions, further underlining their role in waste management.

The concept of a green economy has garnered significant attention in the context of sustainable development and environmental conservation. The potential for organic soil to contribute to a green economy is underscored by numerous studies that highlight the benefits of organic farming practices and their impact on agricultural productivity, and environmental sustainability. Black soldier fly maggot also has a great potencies for develop the green economy through decomposition organic material to be good fertilizer for organic vegetable and the maggots will be high economical stuff for livestock and fisheries feed (Rifai and Permata, 2023).

Organic farming principles, including the use of organic manures and conservation agriculture, have been shown to improve soil fertility, enhance soil organic carbon content, and promote the availability of essential nutrients in the soil(Ramesh et al., 2009; Berbeć et al., 2018). These practices not only contribute to sustainable soil management but also align with the principles of a green economy by promoting environmental sustainability and resource efficiency.

Moreover, the economic implications of organic agriculture and its role in the green economy have been a subject of investigation. Research has examined the economic efficiency of organic farming, its potential for green economic growth, and its contribution to sustainable development (Borel-Saladin & Turok, 2013; Shi et al., 2016; Geng et al., 2022; Anggraeni et al., 2023). These studies provide insights into the economic dimensions of organic agriculture and its relevance to the broader framework of a green economy.

The gap information is that there is no information about nutritional values of medium maggots as organic material decomposed product. The investigator believes that maggot culture medium wills beneficial potency for organic soil. This study showed the nutritional values of medium of black soldier fly maggots enriched food waste from home to look its potency for organic soil.

Materials and Methods

1. Sample Preparation

The study used local wheat bran and food waste as stale food from kitchen. The medium was mixed in plastic box side volume 300 mL with dimensions 10x8x5.5 cm. The lid of the box is given 16 small holes through a soldering iron. A total of 9 plasty boxes were used which were divided into 3 mixed groups, namely A (75:25) group, B (50:50) group and C (25:75) group according to the formula in Table 1. To withdraw BSF, each box containing the mixture was given 1 vial (5 mL) of Petrogenol 800L (PT. Petrokimia Kayaku, Indonesia) containing methyl eugenol 800g/L. The media was then waited for 2 months at ambient temperature. The sample preparation was conducted in the home balcony. After 2 months, the medium sample was observed and continued the process of measuring nutrient levels.

Table 1. The groups and composition of research samples

Groups	Information
Wheat bran	The outer layers of the wheat kernel, removed during milling to produce refined flour.
A (75:25) group	Mixing wheat bran (75%, 75 gram), food waste (25%, 25 gram) and water 100 mL
B (50:50) group	Mixing wheat bran (50%, 50 gram), food waste (50%, 50 gram) and water 100 mL
C (25:75) group	Mixing wheat bran (25%, 25 gram), food waste (75%, 75 gram) and water 100 mL

Fig 1. Petrogenol 800L fly attractant contained Methyl eugenol 800g/L in vial 5mL. Petrogenol 800L image is obtained from E-commerce Shopee.

2. Data collection and analysis

Data nutritional values of wheat bran and medium samples were obtained from proximate test consist of protein, carbohydrate, lipid, water and ash level in percent. Proximate test was conducted by standardized test in Testing Laboratory of Food Quality and Food Safety, Faculty of Agricultural Technology Universitas Brawijaya. Data of nutritional values was compared statistically by One Way ANOVA continued Tukey Post Hoc Test with $p<0.05$ and data were visualized as Bar Chart using Graph Prism ver 9.5.

Results and Discussion

1. Results

The appearance of medium BSF maggots in each group showed a marked difference after 1 month for maggot culture **(Fig 2).** In A (75:25) the group shows not many BSF maggots growing and looks in the form of larval phase BSF maggots. In the B (50:50) group, BSF maggots can grow a lot and the media does not appear to clump. Other results were shown in the C (25:75) group, that the media sample appeared to clump despite the growth of BSF maggots. The results of this appearance show formula B (50:50) gives the best results for BSF maggot media.

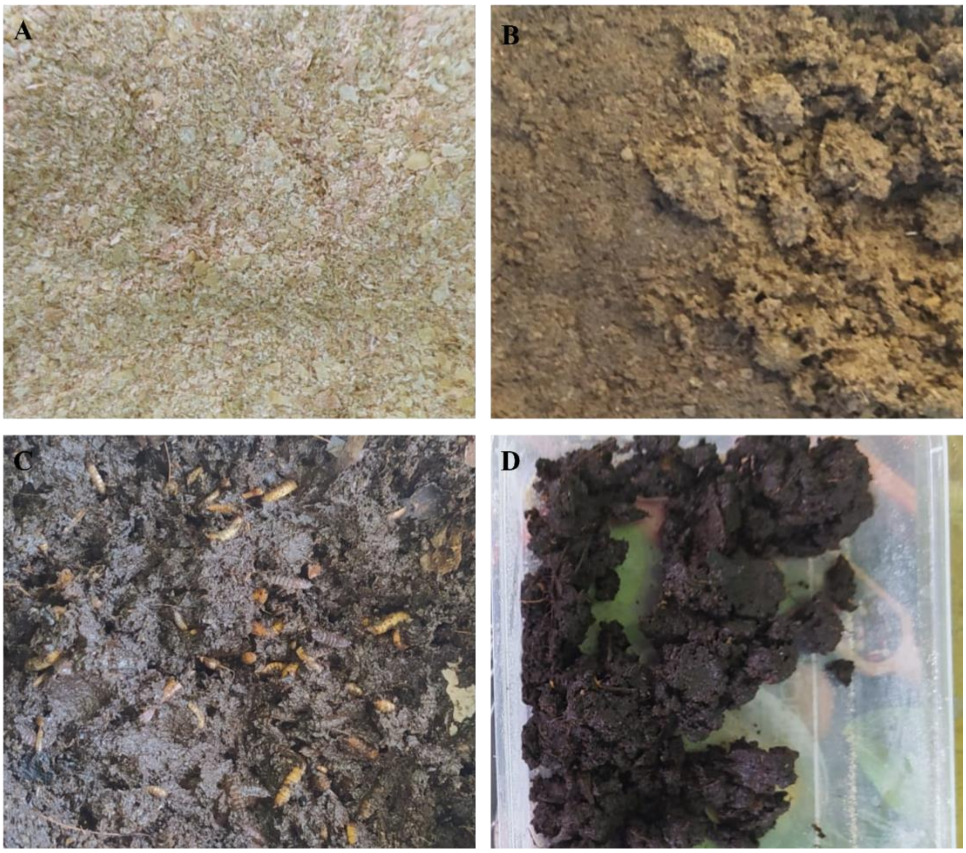

Fig 2. The appearance of wheat bran and the samples. A. Polard; B. A (75:25) group; C. B (50:50) group; D. (25:75) group. The appearance of the sample was a solid wheat bran with fine granules, A (75:25) group looked brown because they was dominated by Pollard and BSF larvae are little visible, B (50:50) group looked black and many BSF maggots grew, while C (25:75) groups appeared to have few maggots growth and medium looked lumpy.

Wheat bran from proximate test results shows that it has a high carbohydrate content (**Table 2 and Fig. 3A).** However, the proximate test results of the maggot medium in each group had different results (**Table 2**). Formula B (50:50) has the highest and most significant medium nutrient content (protein, carbohydrate, lipid, and ash) compared to groups (**Fig 3B-F**). This showed that BSF maggots can utilize nutrients in the medium from wheat bran and household food waste very well in the B (50:50) group. Maggot BSF will decompose organic food waste material and wheat bran and will provide nutritional value to the growth media. Researchers consider that the good nutritional content of the BSF maggot media will be a candidate for organic soil for the further vegetable cultivation. The 50:50 formula between wheat bran and food waste is more attractive to flies for BSF and maggot growth there.

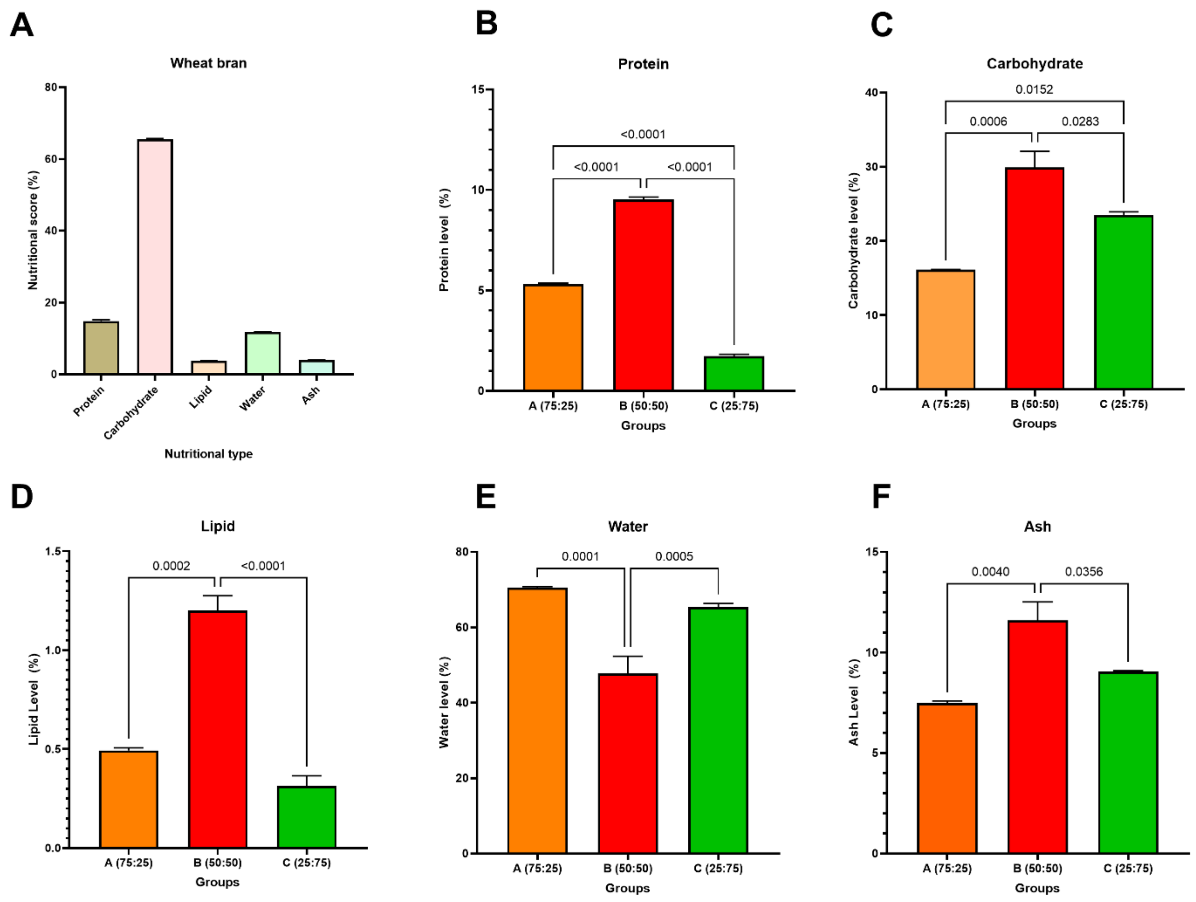

Fig 3. The bar chart of nutritional values of samples. A. Nutritional values of wheat bran. B-F. Statistic comparison among nutritional type in groups. The best performance of nutrition was confirmed in B (50:50) group.

Table 2. The nutritional value of Wheat bran and the samples

Group	Mean Nutritional score ± SEM (%)				
	Protein	Carbohydrate	Lipid	Water	Ash
Wheat Bran	14.87±0.32	65.54±0.18	3.80±0.06	11.79±0.13	4.00±0.04
A (75:25) group	5.33±0.04	16.13±0.03	0.49±0.01	70.56±0.15	7.48±0.10
B (50:50) group	9.53±0.11	29.91±2.17	1.20±0.08	47.77±2.64	11.60±0.92
C (25:75) group	1.74±0.09	23.51±0.41	0.31±0.05	65.38±0.54	9.05±0.05

2. Discussion

To establish organic soil for organic vegetable farming, it is essential to consider the impact of organic farming practices on soil quality, biodiversity, and agricultural productivity. Organic farming has been shown to enhance soil microbial abundance and activity, leading to improved soil health and fertility(Lori et al., 2017). Additionally, organic agriculture has been associated with increased species richness and biodiversity, contributing to the ecological balance and sustainability of agricultural ecosystems(Bengtsson et al., 2005; Tuck et al., 2014). Studies have also demonstrated the positive effects of organic farming on soil properties, such as soil organic carbon content and soil macropore structure, which are crucial for supporting healthy plant growth and nutrient availability(Wang et al., 2021).

Furthermore, the use of organic amendments and management practices in organic vegetable farming has been found to influence soil quality and crop yields. Research has indicated that organic farming systems can lead to higher crop yields and improved soil properties compared to conventional farming practices(Hondebrink et al., 2017; Sheoran et al., 2019). The application of organic waste degrading agents, such as black soldier fly larvae, has shown potential for waste management and soil enrichment, contributing to sustainable farming practices(Orozco-Ortiz et al., 2021; Pazmiño et al., 2023). Moreover, the use of insect protein and frass from insect larvae has been explored as a sustainable alternative for plant fertilization, aligning with the principles of organic farming and waste reduction(Chavez & Uchanski, 2021; Rekha et al., 2022).

This study highlighted various formulations of BSF maggots medium for good organic soil candidate based on their nutrients. This study focused on several nutrients level contained on the medium for the good requirements in crop farming.

The maggot BSF medium enriched food waste contained an amount of protein level (1.74-9.53%) **(Table 2)**. Specific amount of protein levels in soil is uncertain but protein related to nitrogen-containing substance that very important for crop and vegetable growth. The role of soil protein in crop and vegetable farming is crucial for supporting plant growth, nutrient uptake, and overall agricultural productivity. Organic farming practices have been shown to enhance soil protein levels, which are essential for sustainable crop and vegetable production.Bhadha et al. (2021) demonstrated the positive impact of cover cropping on soil protein levels, indicating that soil protein building up over time is a positive change for soil health. This suggests that cover cropping, a common practice in organic farming, can contribute to the enhancement of soil protein, supporting the nutritional needs of crops and vegetables. Moreover, Mukherjee and Lal (2014) emphasized the significance of organic matter in soil, which contains a substantial portion of available nutrients needed for crop growth. This underscores the importance of organic farming practices in maintaining adequate soil protein levels to meet the nutritional requirements of crops and vegetables. Additionally, Xu et al. (2019) showed a positive relationship between soil protein and corn grain yields, indicating the importance of soil protein in supporting crop productivity. This finding further underscores the relevance of soil protein in organic farming systems for the cultivation of vegetables and crops.

The carbohydrate is not directly used by plant for growth. But the carbohydrate from soil can contribute the carbon that necessary for plant growth. This study found the BSF maggot medium enriched domestic food waste has carbohydrate level about 16.13-29.91 %**(Table 2)**. The turnover of carbohydrate carbon in soil plays a significant role in contributing to the carbon content and overall soil health, particularly in the context of organic waste management and agricultural practices.

Derrien et al. (2006) highlighted the relatively great age of carbohydrate carbon in cultivated soil, indicating the potential for physical or chemical protection from degradation, as well as the recycling of soil organic matter carbon by soil microbes. This suggests that carbohydrate carbon contributes to the long-term stability and cycling of soil organic matter, which is essential for sustaining soil fertility and supporting crop and vegetable farming. Furthermore, Navarrete and Tsutsuki (2008) emphasized the rapid decomposition of sugars, indicating that soil carbohydrate-C content contributes to the total soil organic carbon. The turnover of carbohydrate carbon from organic waste inputs influences the overall soil carbon pool, which is essential for maintaining soil fertility and supporting agricultural productivity. In addition, the application of organic wastes has been shown to influence the proportion of organic carbon fractions in the soil, as demonstrated by Chen et al. (2019). The study indicated that the application of organic wastes increased the proportion of organic carbon in different soil fractions, highlighting the role of organic waste in contributing to the soil carbon pool.

Same with carbohydrate, lipid in soil is also not directly utilized by plant. However, lipid is essential to improve the quality of soil for organic farming. The medium BSF maggot enriched food waste of this study has lipid level 0.31-1.20%**(Table 2)**. The lipid fraction of organic waste contributes to the nutrient content in soil, playing a significant role in soil fertility and supporting plant growth. (Diacono et al., 2019) highlighted the phytotoxic and antimicrobial effects of the lipid fraction in organic waste, indicating its potential impact on soil nutrient availability and microbial activity. Additionally, lipid-rich organic waste, such as algal biomass, has been shown to contribute to soil fertility and nutrient availability, as microalgae can accumulate lipids and produce a fuel with desirable properties (Enwereuzoh et al., 2021). Furthermore, the turnover of lipid carbon in soil organic matter is essential for sustaining soil fertility and supporting crop and vegetable growth, as it contributes to the long-term stability and cycling of soil organic matter(Nguyen Tu et al., 2020).

The water content of soil affects the moisture and texture of plant medium. The BSF maggots medium enriched food waste showed having water content about 47.77-70.56% **(Table 2)**. The water content in soil significantly influences crop and vegetable growth. The valuable water in soil insights into the impact of soil moisture on vegetation growth, soil water balance, and crop water requirements, essential for understanding the water needs for crop and vegetable farming.The water content of soil plays a crucial role in the growth and development of crops and vegetables. Soil moisture directly influences water consumption, drought resistance, and precision irrigation in agricultural production(Park et al., 2023). Access to soil moisture is a limiting factor in vegetation growth, affecting evapotranspiration rates and water stress in crops (O'Connor et al., 2019). Soil moisture is an important indicator for crop growth monitoring, yield estimation, and drought monitoring (Yu et al., 2020). Additionally, it influences soil structure, organic matter content, water infiltration, evaporation, and soil temperature, thereby impacting the growth of crops and vegetables(Bannari et al., 2015). Studies have confirmed that crop residue improves soil moisture content, water holding capacity, and the availability of water for plant growth(Khan, 2017). Maintaining high soil water content during sensitive growth stages is crucial for achieving high crop yield(Liao et al., 2008). Predicting soil water is essential for sustainable soil water resource management, controlling soil degradation, vegetation decline, and preventing crop failure in water-limited regions (Bai et al., 2021).

The last nutrient that determined from sample is ash content that related to mineral in soil. The value of ash percentage in studied medium is about 7.48-11.60% **(Table 2)**. The mineral content in soil significantly impacts the growth of crops and vegetables. Soil structure, influenced by mineral content, plays a crucial role in root growth, distribution, and soil microbial activity, ultimately affecting crop yield(Bennett et al., 2012). Ash treatments have been shown to increase soil phosphorus values, particularly when combined with specific crop cultivation, indicating the positive impact of mineral content on soil fertility and crop growth (Schiemenz& Eichler-Löbermann, 2010). Additionally, the application of biochar, which contains minerals from ash, has been found to alleviate deficiencies and improve crop growth(Kiggundu and Sittamukyoto, 2019). However, it is important to note that the influence of ash on soil microbial activity and populations can vary, with some studies showing a decrease in microbial counts with increasing ash content (Pichtel and Hayes, 1990). The effects of ash on soil fertility and crop growth are also dependent on the cultivated crop, highlighting the crop-specific nature of the impact of mineral content on soil (Schiemenz et al., 2011).Furthermore, the application of wood ash, with its high specific surface area and metal oxide content, has been found to enhance soil carbon content, indicating the role of mineral amendments in improving soil quality and potentially benefiting crop growth (Zhao et al., 2018). However, it is essential to consider the variability of ash data, as different sources of ash may have varying effects on soil and crop growth (Van Reuler and Janssen, 1993). Additionally, the application of fly ash to agricultural soils has been studied for its potential to improve crop yields, with observations of increased plant growth and yield with specific fly ash and compost soil ratios(Ghuman et al., 1994). The mineral content in soil also influences the availability of nutrients for plant growth. For example, fresh litter has been identified as a substantial phosphorus source for plant species on infertile volcanic ash soil, indicating the importance of mineral content in providing essential nutrients for plant growth(Katayama et al., 2021). Moreover, soil mineral nitrogen levels have been shown to impact rhizosphere microbial characteristics and cucumber growth, emphasizing the influence of mineral content on soil fertility and crop growth(Cao et al., 2022).

Based on these discussions, the investigators agree that the combination of wheat bran and domestic food waste by 50:50 formulation is the best for BSF maggot growth **(Fig 2)** and has higher significant nutrient content **(Fig 3)** as an organic fertilizer.

Conclusion

This study concluded that Pollard mixed with household food waste as much as 50:50 for BSF maggot cultivation produced the best nutrients to be candidates for organic soil.

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