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Regional Case Study

Planning Sludge Bioconversion Using Black Soldier Fly Larvae in Tofu Production Centers

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Abstract

Sugihmanik Village, Tanggungharjo District, Grobogan Province, is a major tofu-producing area affiliated with 20 MSMEs and the Waste Transportation Authority (PLTA). Although tofu contributes to the local economy, poor wastewater management from fish farming installations can cause environmental issues. The objective of this study was to develop an environmentally friendly and sustainable wastewater management system based on black solid fuel (BSF). The research methodology included water consumption levels and quality, steam generation, and the development of a BSF bioconversion system. The test results showed that the hydroelectric power plant produced 694.21 kg/day (0.68 m3/day) from the wastewater treatment process. The proposed model utilizes the transition of wastewater and the wastewater environment in the BSF ecosystem. This process produces valuable products, including soft BSF larvae as a protein source and BSF waste as raw material.

Keywords: Biotransformation; BSF weeds; circular economy; waste management; wastewater for tofu; WWTP under construction

1. Introduction

In Sugihmanik Village, Tanggungharjo District, Grobogan Province, 30 MSMEs produce 4 tons of soybeans daily for tofu production (Ramadan et al., 2024). Tofu processing produces large amounts of wastewater and increases the organic oxygen demand (BOD), dissolved oxygen demand (COD), and total suspended solids (TSS). Janaka et al., (2025) reported that tofu waste contributed 4,062 mg/L BOD and 15,513.3 mg/L COD, which exceeds the water quality standards set by the 68th Todufubin Combination in 2020 by the Ministry of Environment and Forestry. However, Ramadan et al. (2024) revealed that the wastewater treatment plant (WWTP) still experiences inadequate operation, maintenance, and care, which leads to algae growth. Improper waste disposal causes odor, water discoloration, and environmental noise.

Tofu wastewater contains many contaminants, including long bean starch, proteins, carbohydrates, suspended solids, nitrogen, and excess water. These characteristics suggest that it may be suitable for adaptation. Among major food and beverage crops, black soldier flies (BSF) have been shown to be a major contributor to larval development and adaptation activity due to their poor nutritional status (Diener and Staudt, 2011; Arsada et al., 2026). Several studies have shown that soil micronutrients, especially proteins and carbohydrates, play crucial roles in regulating BSF growth and development (Grassol et al., 2025). Feeding BSF larvae with fruit juices and the consumption of fruits and vegetables have been shown to reduce the risk of bacterial infection (Rahman et al., 2023). Therefore, tofu wastewater has great potential for BSF-based bioconversion.

Sustainable waste management is required to reduce environmental impacts by promoting bio-based waste management. Because conventional waste management methods do not align with circular economy principles, they focus on waste generation and value rather than waste generation (Bhatiyar 2024). In such cases, the application of black soldier fly (BSF) fertilizer or Hermitia alveensis larvae (bioconversion) is one of the most effective treatments for pesticides. According to previous studies, BSF larvae have the potential to destroy ecosystems in a short time and are beneficial for biodiversity conservation (Fajri, N. A., & Hamid, 2021; Vidyasthoti & Sardin, 2020). Larval biomass can also be used as an energy source, contributing to sustainable economic development (Bhatiyar 2024). Therefore, cultivating BSF larvae for the processing and utilization of tofu waste at the WWTP in Sugihmanik City is a feasible approach.

Few studies have been conducted on tofu processing and the implementation of a circular economy in the MSME sector (Hartney et al., 2021; Ramadan et al., 2024). However, research on the development of a BSF bioconversion system for WWTP sludge generated by MSME tofu production is still lacking, particularly regarding local technology and soil constraints. This study presents recommendations for a forest management system using a sustainable and adaptive BSF approach based on the operational characteristics of tofu farmers in Sugih Manik village. The novelty of this study lies in the integration of WWTP sludge, BSF bioconversion, and inhibitors into a sustainable sludge management system for the MSME tofu industry. The proposed project is expected to mitigate environmental damage and provide added value by recycling materials into a circular economy.

2. Method

This study evaluated the feasibility and sustainability of bioconversion technology for black soldier flies in terms of bioconversion efficiency. The evaluation included water testing, soil texture analysis, laboratory testing and technical system design. A methodology was developed to ensure that the proposed system was compatible with the existing operating conditions.

2.1 Location and Time of Research

This study was conducted in Sugihmanik Village, Tulisarjo District, Grobogan Province, Central Java. The study involved 20 micro, small, and medium enterprises (MSMEs) processing tofu at a wastewater treatment plant operated by Tofu Industry Footprint.

Data collection and measurement were conducted during the tofu farmers' working season, from October to November 2025. The sauce was complete with fresh tofu, other ingredients, and water used during the production process. Observations and surveys were conducted to determine the efficiency of the tofu vendors and the wastewater treatment plant in the community.

2.2 Data collection technique

This study used qualitative data collection. Primary data were collected through field observations and interviews using the WWTP operational manual, tofu MSME performance reports, and supporting documents. Monitoring was conducted to assess the condition of the WWTP, including the tofu, waste management, and environmental conditions. The results of this review were used as the basis for developing a wastewater treatment plan based on the use of BSF.

Interviews were selected purposively based on the research objectives, using a purposive sampling technique to maximize the information and relevance (Criswell & Creswell, 2018). Purposive sampling is often used in sustainability studies to obtain a representative sample of participants (Campbell et al., 2020). A survey was conducted to gather information on WWTP operations, waste management, tofu production, environmental impacts, and operational hazards in the study area. The interview results were used as inputs to support the design and development of the proposed program. The categories, selection criteria, and demographics of the respondents in this study are presented in Table 1.

Table 1. Categories, selection criteria, and number of respondents

No.	Respondent Category	Selection Criteria	Role/Representation	Number of Respondents
1.	WWTP planning team	Involved in WWTP planning, supervision, or technical design	Academics, local government representatives, MSME association representatives	4
2.	WWTP operator	Responsible for WWTP operation and maintenance	WWTP technical operator	1
3.	Tofu MSME owners connected to communal WWTP	Directly involved in tofu production and wastewater generation connected to communal WWTP	MSME owners	3
4.	Tofu MSME owners not connected to WWTP	Independently manage wastewater and sludge disposal	MSME owners	2
5.	Community representatives	Living near the WWTP or wastewater disposal area and understanding local environmental impacts	Local residents/community representatives	4
6.	BSF practitioner	Experienced in BSF cultivation and organic waste treatment	BSF practitioner	1
Total Respondents				**15**

2.3 Sampling Techniques

Physical and chemical analyses of the wastewater samples were conducted in accordance with the Indonesian National Standard (SNI 8990:2021), which describes wastewater treatment. In Sugihmanik Village, tofu is produced by a micro, small, and medium-sized enterprise (MSME) in a wastewater treatment plant (WWTP). The current standard sampling procedure was used for all samples throughout the experiment. The test was conducted over 11 h of the MSME's tofu production process to assess water loss during processing. Sampling was performed at 1-hour intervals. At each interval, three wastewater samples were collected at 20-minute intervals to determine the total water sample per hour. This was done to increase the reliability and representativeness of the water samples during the measurements. The wastewater flow rate was determined manually using a volumetric method during the 11 h of operation. All samples and observations were obtained from the wastewater of the tofu MSME in the community water treatment system.

2.4 Sample Parameter Testing Techniques

Wastewater analysis is conducted by soybean-producing companies in accordance with the 2014 Domestic Wastewater Monitoring Note Number 5 from the Ministry of Environment (Ministry of Environment and Forestry Regulation Numbers 68 and 20). The parameters used in this analysis were acidity (pH), organic dissolved oxygen demand (BOD), organic dissolved oxygen demand (COD), total suspended solids (TSS), and coliform concentration. When conducting a pH test, it is important to check the pH value of the solution because it can affect the solution (Al-Mukhtar et al., 2018).

The BOD test is used to measure the oxygen content of organic matter in biological environments, whereas the COD test is used to measure the oxygen content of organic and inorganic compounds. TSS analysis can be used to identify and quantify the impact of pollutants and assess the impact of air pollutants (Alfonso-Muñozgurin et al., 2018). The total coliform test is used for microbial filtration and in wastewater treatment (Gati et al., 2018). Environmental pH was measured using a pH meter, and BOD, COD, TSS, and coliform concentrations were obtained from the laboratory. The experimental methods used to measure the water content are listed in Table 1.

Table 1. Technique testing parameter wastewater samples

No.	Parameter	Method	Principle
1.	Degrees Acidity (pH)	SNI 6 989 .11:2019	pH test with a pH meter
2.	*BioChemical Oxygen Demand* (BOD)	SNI 6989.72:2009	Dissolved oxygen (DO) analysis by Winkler titration
3.	*Chemical Oxygen Demand* (COD)	SNI 6989.2:2019	COD test with reflux closed - spectrophotometry
4.	*Total Suspended Solids* (TSS)	SNI 6989.3:2019	TSS test with gravimetry
5.	*Coliform* Test	AOAC 991.14	Colony enumeration with ready-to-use dry culture media (Petrifilm Plate) after incubation

2.5 Sludge Generation Analysis and BSF System Design

Sludge growth analysis was conducted to measure the amount of sludge produced during tofu processing at the wastewater treatment plant (WWTP). The analysis was conducted using field and laboratory test parameters, including effluent, total suspended solids (TSS), and chemical oxygen demand (COD).

The sludge composition was analyzed using the wastewater treatment methodology and methods proposed by Metcalfe and Eddy (2014). The initial oxygen content was obtained from the TSS removal during the growing season, as shown in Equation (1).

$$TSS_{removed} = Q \times TSS_{in} \times \eta \tag{1}$$

Where $TSS_{removed}$ represents the mass of removed TSS (kg/day), Q is the wastewater flow rate (m^3/day), TSS_{in} is the influent TSS concentration (mg/L), and η is the TSS removal efficiency.

The biological sludge was estimated based on the amount of COD removed and the biomass yield coefficient, as presented in Equation (2).

$$X = COD_{removed} \times Y \tag{2}$$

Where X is the amount of organic matter (kg/day), COD removed (kg/day), and Y is the sampling area. The amount of heat generated was calculated by adding the absorbed heat and then converting it to thermal energy to reflect the operating conditions. The rationale behind the black soldier fly (BSF) genetic modification program is to obtain practical conservation information. Temperature is a key driver of algal growth. Planning can be performed using non-empirical mathematical models.

Larval spawning, egg development, and survival can be estimated using bioconversion parameters, as described by Dortmans et al. (2021). Larval needs are determined by changes in structure and reproduction, whereas egg needs are determined by physiological needs. Furthermore, the outcomes of these ecological changes, such as the loss of larval biomass (i.e., dry BSF larvae) and residue (fly feces), are based on theoretical data and concentration estimates. The formal measurement model is based on efficiency reductions and the introduction of value-added activities into balanced economies.

3. Results and Discussion

3.1 Tofu Wastewater Quantity

The results of measuring the MSME wastewater flow at the WWTP inlet during operation are presented in Table 2. The wastewater flow pattern has different characteristics for industrial applications, where the flow rate increases during the washing and processing of soybeans. The daily average was 61.27 m³/day and increased to 188.33 m³/day from 10:00-11:00 WIB.

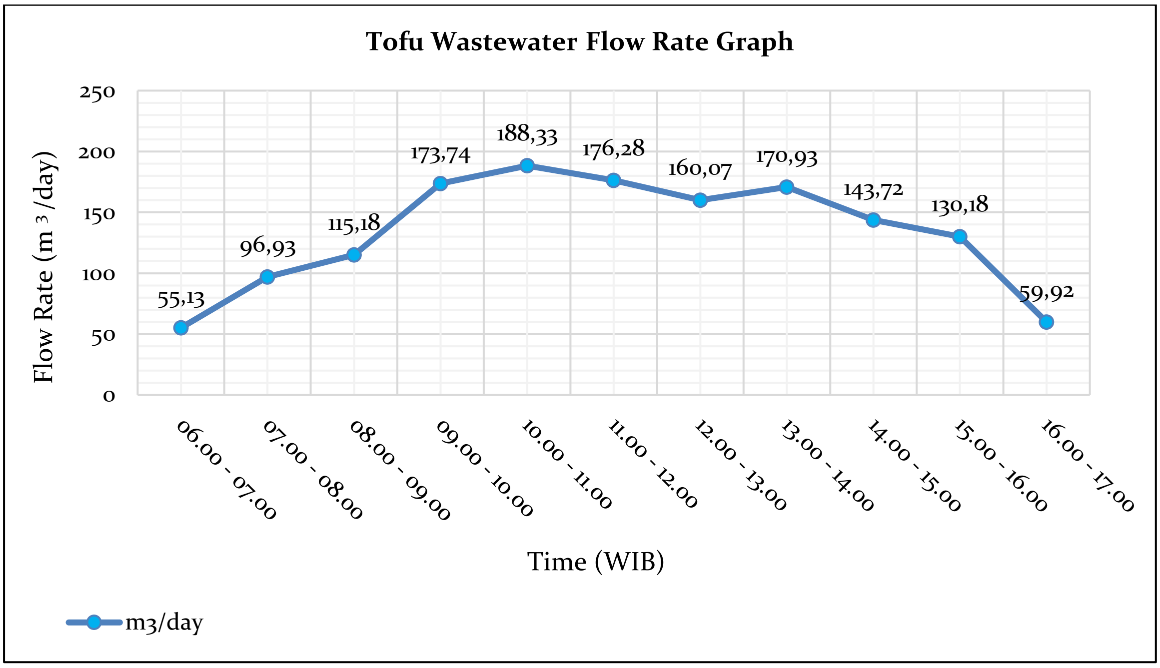

Figure 1. Hourly tofu wastewater flow rate

3.2 Tofu Wastewater Quality

The characteristics of the tofu wastewater at the WWTP inlet point are presented in Table 2.

Table 2. Wastewater quality of tofu micro, small, and medium enterprises

No.	Parameter	Unit	Test Result	Quality standards*	Status
			Physical Parameters		
1.	Turbidity	NTU	708	25	Does not meet the
2.	Temperature	(°C)	28.3	38	Fulfil
			Biological Parameters		
3.	Total Coliform	CFU/100 mL	TNTC (*To Numerous to Count*)	5000	Does not meet the
			Chemical Parameters		
4.	pH	-	4.19	6–9	Does not meet the
5.	BOD_5	mg /L	595.86	150	Does not meet the
6.	COD	mg /L	2136	300	Does not meet the
7.	TSS	mg /L	687	200	Does not meet the

Source: *Regulation of the Minister of Environment Number 5 of 2014

Analysis of the results showed that several compounds exceeded the limits for soybean-processing water. The water had the highest turbidity (708 NTU) and TSS (687 mg/L), indicating that it contained solids and insoluble organic matter remaining from the heat treatment. Tofu water is typically rich in organic matter and is a major source of waste from soybean cleaning, processing, germination, and fermentation (Hajjar et al., 2021). High solubility levels were observed in the mixture, with a BOD5 of 595.86 mg/L and COD of 2,136 mg/L. The decrease in BOD5 and COD emissions can be attributed to the high organic matter produced from biomass and the oxygen demand (Amanda and Jamyati, 2025). The difference between BOD5 and COD in tofu is caused by the presence of difficult-to-degrade organic compounds, such as complex organic and inorganic compounds, in tofu (Wahioni, 2023). This situation in the pharmaceutical and biological sectors leads to increased temperatures during processing (Cranie et al., 2019).

The pH of the wastewater was 4.19, indicating that the wastewater is acidic, which is directly related to whey production during tofu production and pressing. Tofu fermentation is sensitive to acidity due to the formation of organic acids and soluble organic compounds during soybean storage and protein breakdown (Amanda and Jamyati 2025). These acidic compounds reduce bacterial activity and bioactivity, particularly against microorganisms that are sensitive to pH (Hajjar et al., 2021). However, an optimal temperature of 28.3 °C was used to maintain microbial activity during the biological process. However, this measurement may be affected by the combined sampling method, which allows us to measure the temperature of samples collected at different times. Simultaneously, the number of coliforms in TNTC indicates the presence of microorganisms. Tofu production contains many microorganisms in wastewater, which can lead to increased coliforms and decreased wastewater quality (Wahyuni et al., 2023).

3.3 Analysis of Tofu Waste Sludge at WWTP

The wastewater treatment plant consists of a sedimentation unit and an anaerobic biodigester for wastewater treatment. The characteristics of sludge are determined by the characteristics of the water entering the wastewater treatment plant. High BOD5, COD, and TSS levels indicate that these organisms may be involved in biodegradation.

For odor, the liquid used to cook the tofu was heated to a smooth, creamy consistency. The top must be closed to sample the flow during heat treatment. The presence of a foul odor indicates anaerobic decomposition, which is susceptible to degradation. The structure of the wastewater treatment plant is illustrated in Figure 3.

Figure 2. Waste sludge from tofu industries

This allows WWTP sludge to be treated as an environmental pollutant and a potential source of pollution. The high biomass content of frozen tofu demonstrates its high potential for biological activity. Tofu WWTP sludge is typically rich in organic compounds, including proteins and carbohydrates, which are essential for bacterial and fungal growth (Arnon et al., 2022).

Black soldier fly larvae (BSF) are a promising solution for waste management. BSF larvae can reduce fertilizer use for biomass production and growth (Grassel et al., 2022). The high organic matter and water content of tofu enhances the efficiency of BSF-based WWTP sludge bioconversion. BSF bioconversion makes tofu a low-cost, sustainable, and high-value feedstock for WWTP sludge treatment.

3.4 Sludge Generation from Tofu MSMEs Waste

In the case of a wastewater treatment plant (WWTP) for a tofu-based MSME, growth stems from two factors:

1) primary pollution caused by pre-treatment and
2) biological fermentation resulting from the growth of microorganisms in the biological system (biodigester and anaerobic biofilter).

Using statistical methods to analyze the soil development process, the total specific gravity (TSS) was obtained as the initial solute, and chemical oxygen demand (COD) was used to measure the degradation rate. This response is based on the weighting of physical and chemical factors, with the primary factors being the physical and chemical aspects of the system (Metcalf and Eddy, 2014).

According to the study, the tofu processing unit of an MSME produces 34.71 kg/day of dry waste, followed by 29.46 kg/day of primary waste, and 5.25 kg/day of finished waste. By increasing the Total Solids (TS) fraction by 5% and 1.02, the total becomes 694.21 kg/d or 0.68 m3/day. These data are consistent with the effects of tofu processing and high biomass on wastewater treatment systems. The heat flux estimates used in this study were based on Metcalf and Eddy (2014), which included both heat flux and heat loss. The top of the first gradient represents the growth of several granules that settled during a single settling event. This is consistent with the characteristics of tofu wastewater, which has low TSS levels and organic matter from soybean waste and protein particles.

The rate of biological sludge production is low because most wastewater treatment plants use anaerobic treatment technologies. The combination of anaerobic and aerobic processes results in lower COD removal rates because of environmental pollution (Metcalf and Eddy, 2014). This is important from a practical perspective because it reduces the number of concurrently developed drugs containing many antimicrobials. Tofu waste is a rich source of organic matter that can be used as a fertilizer for black soldier fly (BSF) larvae. According to several previous studies, BSF larvae can consume water containing organic matter and convert it into valuable bioactive compounds (Dortmans et al., 2019; Dortmans et al., 2021). The use of a wastewater treatment plant (WWTP) for BSF feeding can reduce the amount of wastewater and replenish the nutrients needed by the ecosystem.

3.5 Bioconversion of Wastewater Treatment Plant Sludge with *Black Soldier Fly*

The WWTP sludge bioconversion system converts wastewater into human food at a 3:1 ratio. This ratio was used in the initial experiments to determine the optimal conditions for BSF larval growth and nutrition. It is expected that increasing the food supply of the population will reduce plant water use while simultaneously increasing the protein and fiber content to create a more balanced biomass in the conversion process. The total feed yield was 694.21 kg/d, of which 231.40 kg/d was derived from waste and 925.61 kg/d was produced. The goal of supplementation is to improve the C/N ratio, nutrient content, and material composition to promote BSF larvae growth. This partnership will enable local storage and expand the scope beyond the management of sludge.

BSF sludge can reduce organic matter by up to 80% (Dortmann et al., 2021). This model is based on a 75% probability distribution to account for other factors related to different field conditions, such as depth, soil moisture content, and environmental factors, such as temperature and humidity variations, which affect larval feeding behavior. These figures show that the biomass conversion process productivity reached 694.21 kg/d, and the residual BSF yield was 231.40 kg/d.

The transformation process produced a larval biomass of 149.76 kg per day, demonstrating that wastewater treatment, which is a low-value waste, can be converted into high-value waste in the BSF process. The biotransformation method demonstrated that BSF are highly efficient in decontaminating laboratory wastewater. Previously, it has been reported that BSF species can produce higher yields and reduce long-term growth rates (Grossol et al., 2025). Furthermore, BSF species have been shown to be able to adapt to various food habitats, especially fruits and vegetables (Dortmans et al., 2021; Lalander et al., 2019), suggesting that BSF may have the ability to prey on other species. The biotransformation activity of BSF in tofu can be an important factor in the production of tofu by MSMEs in terms of sustainable use.

3.6 Harvesting and Processing of Bioconversion Products

The biological transformation process involves substrate addition, organism growth, organic matter degradation and product dissociation. Larval maturation occurs at 12 weeks of age when larvae reach 17 weeks of age (Dortmans et al., 2021). This interaction is designed to maximize larval biomass before reaching the pre-pupal stage, when the feeding activity decreases. Theoretically, at this stage, the rate of biodegradation and biomass conversion to larval biomass is optimal, which contributes significantly to larval biomass growth.

The separation of larvae and biocorrosion residues was developed using a two-stage test method with 7 and 3 mm mesh diameters. Loose residues were filtered through the first 7 mm mesh screen, and larvae and smaller residues were filtered through the second 3 mm mesh screen. The 2 mm mesh screen allowed for fragment separation, whereas the 3 mm mesh screen was used to separate larger particles for larvae. Using this technique, it has been shown that larval fractions can be distinguished from different species (Dortmans et al., 2021). The mesh size was chosen to maximize the distribution and facilitate subsequent processing steps.

The transformation results were divided into larval biomass and residue (feces) fractions. Larval biomass can be dried for processing or used as a value-added commercial product. Simultaneously, the residue fragments can be further divided into small, brittle residue fragments. The intact residue, which has high stability characteristics, can be used as a fertilizer. The undigested residue, which contains intact organic matter, is added to aerobic compost to achieve the fermentation stage (Lalander et al., 2019). This collection and processing ensures that all waste from the transformation process is recycled.

3.7 Conditioning and Processing

The recovered larvae undergo a cleaning process to remove allergens, disinfect, and ensure hygiene. Drying larvae during incineration reduces their moisture content and increases the shelf life of the product. The lower the loss per unit weight, the better the frozen BSF for production. Appropriate temperature and time are required to minimize food spoilage caused by elevated temperatures.

The residues used in this study were divided into two categories: fine and weak residues. Fine residues are incorporated into stable, non-volatile soil after conversion in the storage system (Klamsteiner et al., 2020; Sarpong et al., 2019). Larger residues, which still contain intact organic matter, are prepared for aerobic composting until they reach maturity. Compliance with these regulations is crucial for transforming the entire ecosystem, thereby increasing tofu production and yield (Lopes et al., 2022; Eslin et al., 2022).

Biomass and compost stability were measured using the carbon-to-nitrogen (C/N) ratio, water content, nitrogen (N), phosphorus (P_2O_5), potassium (K_2O), iron (Fe), and lead (Pb). A stable compost mass is often associated with a high C/N ratio, slow biomass decomposition, and low nutrient availability, leading to increased biomass production. This system is often used to monitor degradation, nutrient availability, and biodiversity (Klamsteiner et al., 2020; Sari et al. 2022).

3.8 Final Products and Potential Utilization

The tofu production process in a wastewater treatment plant (WWTP) involves two types of waste: larval biomass in dry water and residual organic matter in wet water. Larval biomass from sewage sludge is rich in protein and lipids and can be used as feed for poultry and fish farms. At the same time, sewage sludge is produced through biochemical reactions that ultimately produce fertilizers and soil-based preparations that can be used as fertilizers to improve soil fertility and ecological characteristics. The use of these two technologies can increase the cost of a WWTP and reduce the efficiency of wastewater treatment.

This transformation produces larval biomass of 149.76 kg per day. Of this loss, 50% was expected to be marketable, and 50% of births were lost. Furthermore, the weed biomass was 74.88 kg per day. Drying is performed to reduce the water volume and increase the storage capacity. The drying process resulted in a 50% weight loss, and the active form was the Dried Black Wool Larvae. The dried black stink flies weighed 37.44 kg/d. A special box, about the size of a coin, with a small amount of filling, contains a group of animals and fish inside for additional benefits.

Data were collected from calcium-scented fly droppings (BSF droppings), with 231.40 kg per day. Scented fly urine is classified as biocompatible and can be used as a fertilizer. Black stink flies benefit plants by reducing fertilizer use and are tolerant of chemical fertilizers. The BSF bioconversion system not only functions as a separator for wastewater treatment plants (WWTPs) but also contributes to the development of wastewater treatment MSMEs. Table 4 summarizes the end markets for genetic modification (Ramadan et al., 2024; Sari et al., 2022).

(a) **(b)**

Figure 3. Illustration of final bioconversion products
Dried black soldier fly larvae (a) and black soldier fly frass fertilizer (b)

3.9 BSF-Based Tofu Waste Sludge Management System

The tofu solid waste (BSF) treatment system designed for a tofu wastewater treatment plant (WWTP) is shown in Figure 4. As shown in Figure 4, the process consists of (1) tofu WWTP effluent and food residue, (2) BSF, (3) BSF, (4) recycling, (5) disposal, and (6) disposal.

Tofu WWTP sludge was mixed with feed residue at a 3:1 ratio to increase nutrient availability and encourage microbial growth. During biotransformation, BSF larvae reduce the amount of biomass they produce and waste products. These products have added value, such as fertilizer and black fruit fly larvae, which provide financial support to tofu MSMEs and facilitate better waste management practices.

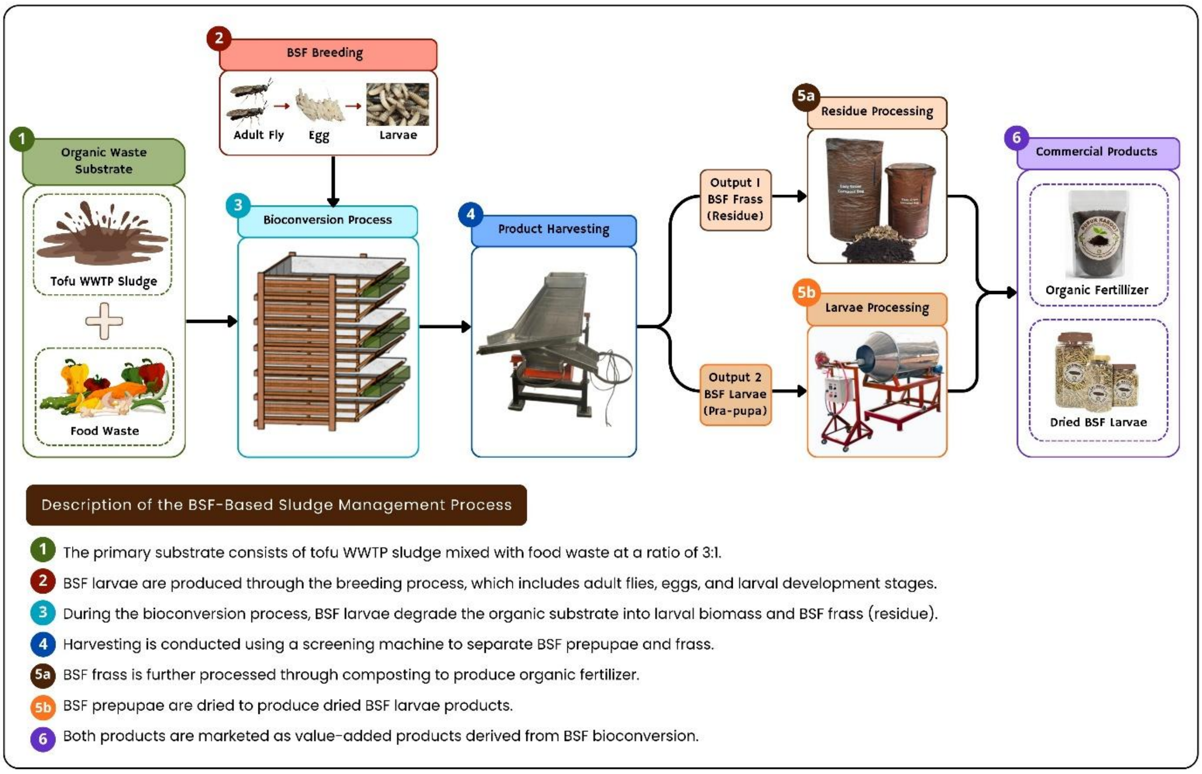

Figure 4. Schematic of a black soldier fly-based tofu wastewater sludge management system

This policy covers both wastewater and organic waste phases using BSF bioconversion methods.

4. Conclusion

The analysis conducted in this study indicates that tofu waste can be used as a fuel in BSF production. Depending on the formulation, additives can be used to inoculate BSF larvae, and the residue can be used as a modifier. The use of a bioconversion system in a WWTP is not only feasible but also economical. Therefore, these materials not only serve as food sources but also act as vital groundwater sources for the ecosystem.

Therefore, a BSF biorefinery represents a viable and sustainable alternative to tofu for MSMEs. However, this research is still in its early stages, and further studies are needed to confirm the feasibility of the proposed framework. Further research is needed to determine the influence of larval diet, nutrition, and development, as well as their relative importance. Furthermore, maintaining product quality, compost quality, and quality assurance is crucial for compliance with environmental and agricultural regulations. Financial feasibility and comparative analyses are needed to determine the feasibility of the project at the MSME level.

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Ethics Statement

This study did not involve human participants, animals, or sensitive data; therefore no ethical approval was required.

CRediT Author Statement

Budi Prasetyo Samadikun: Idea Development, Research Design, Supervision, Manuscript Review and Revision. **Sri Sumiyati**: Supervision, Manuscript Review and Revision. **Bimastyaji Surya Ramadan**: Supervision, Resources, Manuscript Review and Revision. **Lutfiana Anisa**: Investigation, Formal Analysis, Data Curation, Visualization, Manuscript Draft Preparation. **Chintya Putri Agustin**: Investigation, Formal Analysis, Data Curation, Visualization. **Irfan Tawakkal**: Manuscript Draft Preparation, Supervision, Manuscript Review

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