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Black Soldier Fly Bioconversion for Sustainable Organic Waste Management: A Systematic Review and Circular Economy Framework

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Abstract

Organic waste is a major environmental challenge due to increasing generation and limitations in conventional waste management systems. This study systematically reviews the potential of Black Soldier Fly (BSF) (Hermetia illucens) bioconversion as an integrated approach to sustainable organic waste management. A qualitative systematic literature review was conducted through structured literature searching, screening, data extraction, and thematic synthesis using the PRISMA 2020 framework. The findings indicate that BSF larvae can rapidly reduce organic waste while producing protein-rich larval biomass and nutrient-rich frass. Bioconversion performance is influenced by substrate characteristics, temperature, moisture, aeration, larval density, and operational management. Beyond waste reduction, BSF technology supports resource recovery, alternative feed production, organic fertilizer generation, landfill diversion, and circular economy development. The main contribution of this review is an integrated conceptual framework linking BSF bioconversion with environmental benefits, economic value creation, and sustainable resource management. The findings demonstrate that BSF technology should be considered not merely as a waste treatment method but as an integrated strategy for sustainable organic waste management and circular economy implementation.

Keywords: larval biomass production, organic residue valorization, biological conversion, waste-to-resource systems, insect protein, organic fertilizer, environmental sustainability.

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Introduction

Food waste has become one of the most critical environmental and sustainability challenges worldwide due to its continuously increasing generation and the complexity of its impacts on economic, environmental, and social systems. The continuous growth of food waste not only represents the inefficient use of natural resources including water, land, energy, labor, and capital but also contributes significantly to greenhouse gas emissions, environmental pollution, and the depletion of future food resources [1]. Consequently, ineffective food waste management has become a major obstacle to achieving sustainable development, particularly in relation to responsible consumption and production, climate action, and sustainable urban development [2]. These challenges have encouraged many countries to seek innovative waste management approaches that not only reduce waste accumulation but also recover valuable resources through sustainable treatment technologies.

In Indonesia, the management of organic waste remains a significant environmental issue because biodegradable waste constitutes the largest proportion of municipal solid waste. Rapid urbanization, increasing population density, changing consumption patterns, and growing food demand have substantially increased the amount of organic waste generated by households, traditional markets, restaurants, and agricultural activities. However, waste management systems in many Indonesian cities continue to rely predominantly on conventional collection-and-disposal approaches, which have demonstrated limited effectiveness in reducing waste accumulation and mitigating environmental pollution [3]. As a consequence, increasing quantities of untreated organic waste continue to be transported to final disposal sites, accelerating landfill overcapacity while simultaneously contributing to greenhouse gas emissions, unpleasant odors, leachate formation, and ecosystem degradation.

These challenges are particularly evident in Bima City, Indonesia, where several districts experience relatively high population density while waste management infrastructure remains inadequate. The existing system is characterized by limited waste collection coverage, insufficient temporary waste disposal facilities (TPS), and the widespread occurrence of illegal dumping sites [4]. Furthermore, only approximately 47.8% of the generated waste is transported to final disposal sites, leaving a substantial proportion unmanaged and increasing the potential for environmental contamination [5]. Poorly managed organic waste has been reported to degrade environmental quality through surface water pollution, unpleasant odors, increased pathogen proliferation, and declining public health conditions. Previous studies have also demonstrated that ineffective waste management practices contribute directly to the deterioration of surface water quality and environmental sustainability [6], [7]. These conditions indicate that improving organic waste management is no longer solely a sanitation issue but has become an essential component of sustainable environmental management.

The limitations of conventional waste management systems have prompted the exploration of alternative technologies capable of processing organic waste more efficiently while simultaneously generating economic value. Among various biological waste treatment methods, Black Soldier Fly (BSF) (*Hermetia illucens*) larval bioconversion has emerged as one of the most promising environmentally friendly technologies [7]. BSF larvae possess an exceptional ability to consume and biologically convert diverse organic waste substrates, including household food waste, market waste, livestock manure, and agricultural residues, within a relatively short period. Compared with conventional composting methods, BSF bioconversion offers faster decomposition rates, greater waste reduction efficiency, and the ability to recover valuable biological resources from organic waste [8].

The advantages of BSF technology extend beyond waste reduction. During the bioconversion process, organic waste is transformed into high-value products, including larval biomass rich in protein and lipids that can be utilized as alternative animal feed, as well as frass containing nutrients suitable for organic fertilizer production [9]. Consequently, BSF technology simultaneously addresses two major environmental challenges: reducing organic waste accumulation and increasing resource recovery through circular economy practices. Furthermore, BSF cultivation requires relatively limited land area, simple operational procedures, and comparatively low investment costs, making it highly suitable for decentralized waste management systems at household, community, and municipal levels [10]. These characteristics position BSF bioconversion as an attractive alternative for countries such as Indonesia, where the availability of waste treatment infrastructure remains limited.

Despite the increasing number of studies investigating Black Soldier Fly technology, existing literature has predominantly examined BSF from fragmented perspectives. Previous studies have mainly focused on household food waste generation and disposal behavior [11], weaknesses of conventional waste management systems and community participation, environmental impacts resulting from uncontrolled waste disposal [12], or the biological performance of BSF larvae in reducing organic waste [13]. Although these studies provide valuable scientific evidence, they generally discuss each aspect independently. A comprehensive synthesis integrating biological mechanisms, operational determinants, environmental impacts, and resource recovery into a unified framework for sustainable organic waste management remains limited [14]. Consequently, current literature provides insufficient understanding of how BSF bioconversion can be systematically implemented as an integrated waste management strategy rather than merely a biological waste treatment technology.

Therefore, the novelty of this study lies in the development of an integrated conceptual framework that synthesizes existing scientific evidence on BSF-based organic waste management from multiple complementary perspectives. Unlike previous review studies that primarily emphasize the efficiency of waste reduction or the biological characteristics of BSF larvae, this study integrates four interconnected dimensions, namely (1) the biological mechanism underlying BSF bioconversion, (2) operational factors determining decomposition efficiency, (3) environmental benefits resulting from BSF implementation, and (4) resource recovery through the production of value-added outputs that support circular economy principles. Through this multidimensional synthesis, the present study provides a more comprehensive understanding of BSF technology as an integrated optimization strategy for sustainable organic waste management. This conceptual perspective not only strengthens the scientific foundation of BSF utilization but also offers evidence-based insights that may assist policymakers, local governments, and communities in designing more effective and sustainable organic waste management systems, particularly in developing countries.

Accordingly, this study addresses the following research questions: (1) how is organic waste processed through BSF bioconversion, and (2) how can BSF utilization optimize organic waste management. Based on these research questions, this study aims to analyze the biological process of organic waste conversion through Black Soldier Fly larval bioconversion, evaluate the effectiveness of BSF technology in reducing organic waste, and formulate an integrated optimization strategy for sustainable organic waste management based on scientific evidence. The findings are expected to contribute to the advancement of sustainable waste management knowledge while providing practical recommendations for implementing BSF-based organic waste treatment as part of a circular economy-oriented environmental management strategy.

Method

This study employed a qualitative systematic literature review to identify, examine, and synthesize scientific evidence concerning the application of Black Soldier Fly (BSF) (Hermetia illucens) larvae for organic waste management. A literature-based approach was selected because the objective of the study was to integrate findings from previous scientific studies regarding the effectiveness of BSF bioconversion, environmental and operational requirements, resource recovery, and its potential contribution to circular economy implementation [15]. Rather than generating primary experimental data, this study systematically analyzed secondary evidence obtained from relevant scientific publications.

The research procedure consisted of sequential stages, including research planning, literature searching, study selection, data extraction, content analysis, evidence synthesis, framework synthesis, and reporting of findings and novelty. The overall research workflow is presented in Figure 1.

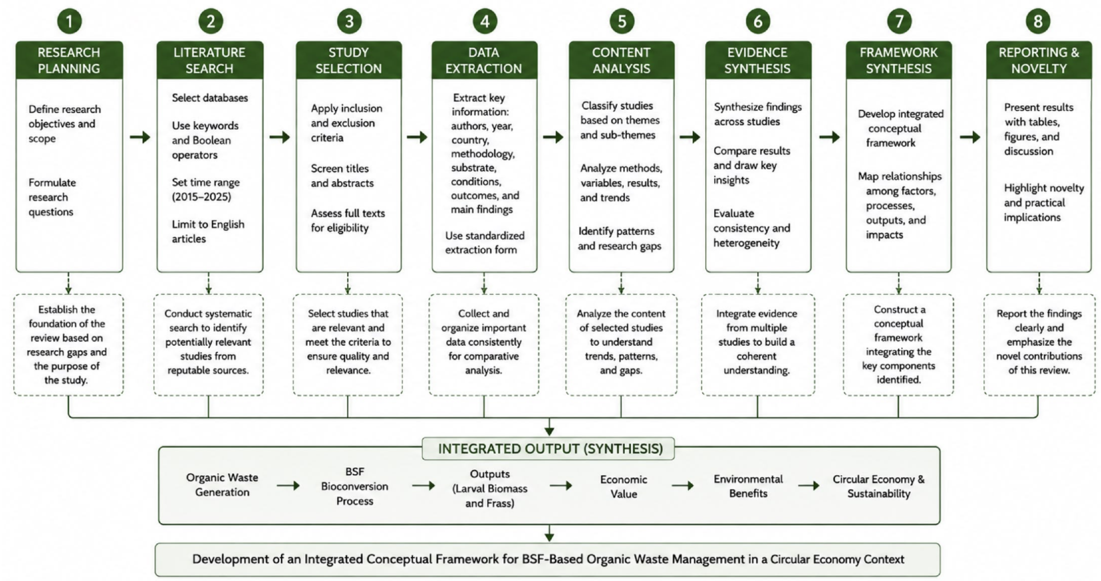

Figure 1. Research Workflow

a. Literature Search Strategy

The literature search was conducted by identifying scientific publications related to BSF bioconversion, organic waste management, waste reduction, resource recovery, and circular economy. The search strategy was designed to capture studies discussing both the biological performance of BSF larvae and their broader environmental and economic implications.

The search process used combinations of keywords and Boolean operators related to the research focus, including "Black Soldier Fly," "BSF," "Hermetia illucens," "organic waste," "food waste," "biowaste," "bioconversion," "composting," "degradation," "valorization," "circular economy," and "sustainability." The search was restricted to scientific publications written in English and published within the defined study period. Relevant publications were retrieved from reputable scientific databases and publisher platforms.

The literature search was followed by systematic screening to identify publications that directly addressed the research questions. The selection process was documented using the PRISMA 2020 framework to improve transparency and reproducibility in the identification, screening, eligibility assessment, and inclusion of scientific studies.

b. Study Selection and Eligibility Criteria

The selection of studies was conducted through several stages. First, all records identified from the literature databases were compiled and duplicate records were removed. Second, titles and abstracts were screened to exclude publications that were clearly unrelated to BSF, organic waste management, or bioconversion. Third, the full texts of potentially relevant publications were assessed against predefined eligibility criteria.

Studies were included when they: (1) focused on BSF or *Hermetia illucens* and its application in organic waste management or bioconversion; (2) reported relevant outcomes or performance indicators related to waste reduction, larval growth, biomass production, environmental performance, or resource recovery; (3) were original research articles or relevant review articles; and (4) were published in peer-reviewed scientific journals within the specified publication period.

Studies were excluded when they were unrelated to BSF or organic waste management, lacked sufficient information relevant to the research questions, or were non-scientific publications. The complete study identification and selection process is summarized in Figure 2.

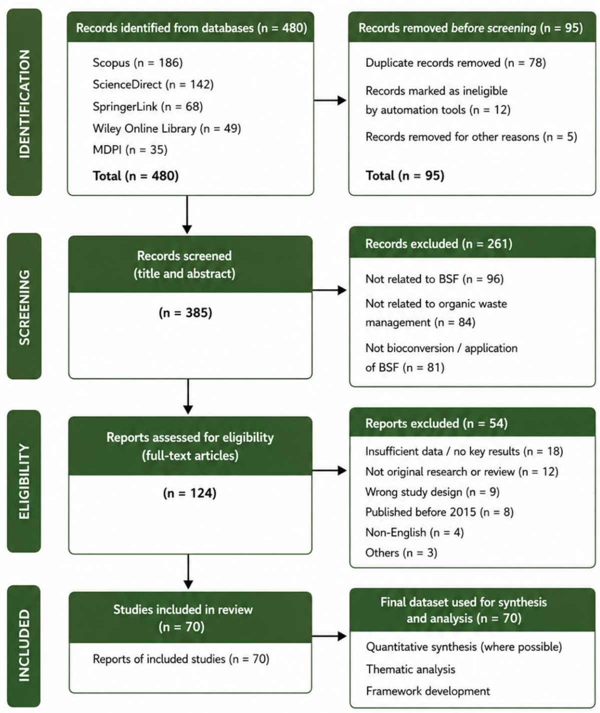

Figure 2. PRISMA 2020 Flow Diagram of Literature Selection

c. Data Extraction

Data from the selected publications were extracted systematically using a standardized data extraction approach. The extracted information included author and publication year, study location or country, research methodology, type and characteristics of organic waste, BSF treatment conditions, environmental parameters, waste reduction performance, larval growth and biomass production, nutritional characteristics of larval biomass, frass characteristics, environmental benefits, economic implications, and major findings.

Particular attention was given to evidence concerning the effectiveness of BSF larvae in reducing organic waste and converting biodegradable materials into value-added products. Information regarding waste reduction efficiency and the economic value of larval biomass was synthesized from relevant previous studies, including Bekier et al [16]. Evidence concerning household food waste behavior, conventional waste management systems, public participation, and the environmental consequences of inappropriate waste disposal was also considered based on previous studies [17].

d. Data Analysis and Evidence Synthesis

The collected data were analyzed using qualitative content analysis and thematic synthesis. The analysis involved several sequential activities. First, relevant information was reduced and classified according to the main research themes. Second, findings were compared across studies to identify common patterns, differences, and important evidence concerning BSF bioconversion. Third, the findings were synthesized into three major thematic dimensions: (1) the effectiveness of BSF bioconversion in organic waste reduction; (2) the environmental and operational performance of BSF-based organic waste management; and (3) the role of BSF bioconversion as an integrated strategy for circular economy and sustainable organic waste management.

The synthesis further examined relationships among biological conversion mechanisms, environmental conditions, operational requirements, waste reduction, larval biomass production, frass utilization, environmental benefits, and economic value. This process enabled the study to move beyond a descriptive summary of previous research toward an integrated interpretation of how BSF technology can contribute to sustainable organic waste management.

Finally, the synthesized evidence was used to develop an integrated conceptual framework connecting organic waste generation, BSF bioconversion, resource recovery, environmental benefits, economic value creation, and circular economy principles. The framework was subsequently used to identify strategic implications and research opportunities for the implementation of BSF-based organic waste management.

Result and Discussion

The literature reviewed in this study demonstrates that Black Soldier Fly (BSF) bioconversion represents one of the most promising biological approaches for optimizing sustainable organic waste management. Previous studies consistently report that BSF larvae are capable of rapidly degrading various types of organic waste while simultaneously generating economically valuable products, including protein-rich larval biomass and nutrient-rich frass [18]. Beyond its technical capability in waste reduction, BSF technology also contributes to environmental protection through pollution mitigation, supports circular economy implementation by recovering valuable resources from waste streams, and offers practical opportunities for decentralized waste management at household and community levels.

To provide a comprehensive understanding of the role of BSF in sustainable organic waste management, the findings of this literature review are synthesized into three major thematic discussions. The first section examines the effectiveness of BSF bioconversion in reducing organic waste, focusing on the biological mechanism of waste degradation, larval growth performance, biomass production, and waste reduction efficiency. The second section discusses the environmental and operational performance of BSF-based waste management, including ecological characteristics of BSF, operational requirements, environmental safety, and factors influencing the effectiveness of the bioconversion process. Finally, the third section presents BSF bioconversion as an integrated strategy for circular economy and sustainable waste management, highlighting the environmental, economic, and policy implications of BSF implementation while proposing an integrated conceptual framework for optimizing organic waste management [19].

Overall, this thematic organization enables a systematic synthesis of previous scientific findings and provides a comprehensive perspective on how BSF bioconversion can evolve from a biological waste treatment technology into an integrated strategy for achieving environmentally sustainable and circular economy-oriented organic waste management.

a. Effectiveness of Black Soldier Fly (BSF) Bioconversion in Organic Waste Reduction

The effectiveness of Black Soldier Fly (BSF) (Hermetia illucens) bioconversion has been widely recognized as one of the most promising biological solutions for addressing the increasing volume of organic waste generated by households, traditional markets, food industries, and agricultural activities. The scientific literature consistently demonstrates that BSF larvae possess an exceptional capacity to consume and convert biodegradable waste into valuable products within a relatively short period. Unlike conventional composting, which generally requires several weeks to months for complete decomposition, BSF larvae can substantially reduce the volume and weight of organic waste within approximately two to three weeks under optimal environmental conditions [20]. Various studies report that waste reduction efficiencies range from 70% to 85%, depending on substrate composition, larval density, moisture content, and temperature.

The remarkable degradation capability of BSF larvae is primarily attributed to their highly efficient digestive system. During the larval stage, BSF secretes various digestive enzymes, including cellulase, protease, and lipase, which facilitate the decomposition of complex organic compounds such as cellulose, proteins, carbohydrates, and lipids into simpler nutrients that support rapid larval growth [21], [22]. This enzymatic activity accelerates organic matter decomposition while simultaneously reducing the accumulation of biodegradable waste that would otherwise contribute to greenhouse gas emissions and landfill overloading. Consequently, BSF bioconversion serves not only as a waste treatment technology but also as a biological resource recovery process that transforms waste into economically valuable products.

Another significant indicator of BSF effectiveness is its ability to convert organic waste into high-quality larval biomass. Numerous studies have demonstrated that substrates rich in carbohydrates and proteins, including household food leftovers, rice residues, bakery waste, and meat scraps, significantly improve larval growth performance and biomass production [23]. Under favorable rearing conditions, processing one ton of organic waste may produce approximately 150–250 kg of fresh larvae, which contain crude protein levels reaching 40–45% and lipid contents exceeding 30%. Such nutritional characteristics make BSF larvae an increasingly attractive alternative protein source for aquaculture, poultry, and livestock industries while reducing dependence on conventional feed ingredients such as fish meal and soybean meal.

The effectiveness of BSF bioconversion extends beyond waste reduction and biomass generation. The residual substrate remaining after larval feeding, commonly referred to as frass, contains considerable amounts of organic matter and essential nutrients that can be utilized as organic fertilizer [24]. Therefore, nearly every output generated during the bioconversion process possesses economic value, reflecting the fundamental principles of resource efficiency and circular economy. This integrated utilization distinguishes BSF technology from many conventional waste management approaches that often generate limited by-products.

Overall, the reviewed literature demonstrates that the effectiveness of BSF bioconversion should not be evaluated solely by its waste reduction capacity but also by its ability to recover valuable biological resources, shorten waste processing time, and create multiple environmental and economic benefits simultaneously. These findings indicate that BSF technology represents an integrated biological system capable of supporting sustainable organic waste management while contributing to resource recovery and circular economy implementation.

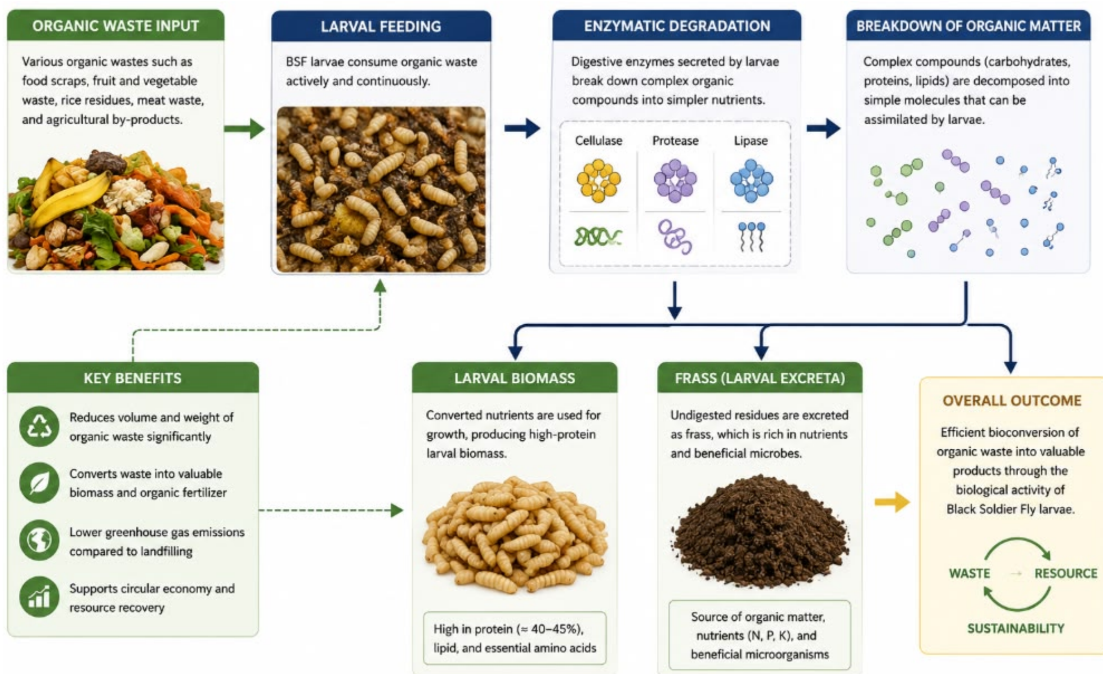

Figure 3. Biological Mechanism of Black Soldier Fly (BSF) Bioconversion

Figure 3 illustrates the biological mechanism through which BSF larvae convert organic waste into valuable biomass and organic fertilizer. The process begins with the introduction of biodegradable waste into the larval feeding substrate, where BSF larvae actively consume various organic materials, including food residues, fruit waste, vegetables, and agricultural by-products. During feeding, digestive enzymes such as cellulase, protease, and lipase break down complex organic compounds into simpler nutrients that are subsequently assimilated into larval biomass. As the larvae continue feeding, the overall volume and mass of organic waste decrease substantially, while nutrients are redistributed into two valuable products: protein-rich larval biomass and nutrient-rich frass [25]. This biological conversion process demonstrates an efficient transformation of waste into reusable resources without relying on intensive chemical or mechanical treatments. The figure highlights the central role of BSF larvae as biological agents that simultaneously reduce waste accumulation, recover nutrients, and produce economically valuable outputs. Consequently, the BSF bioconversion mechanism represents the fundamental biological basis supporting sustainable organic waste management and circular resource utilization.

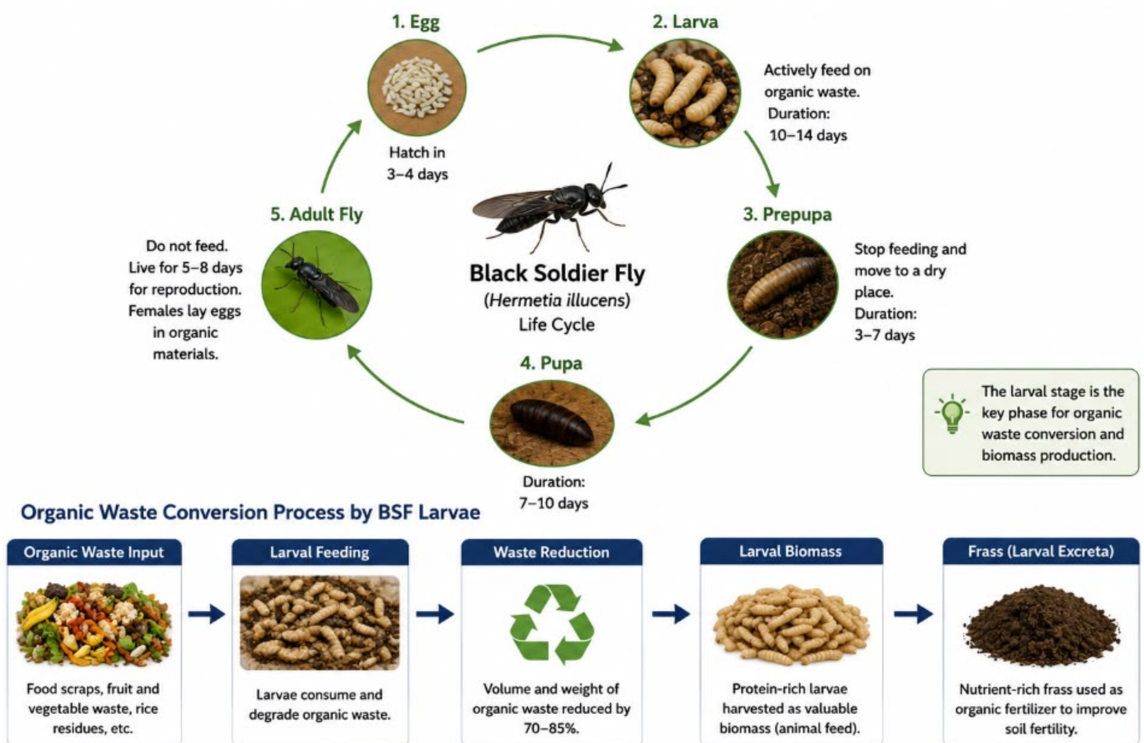

Figure 4. Life Cycle of Black Soldier Fly and Organic Waste Conversion Process

Figure 4 presents the relationship between the life cycle of Black Soldier Fly and the organic waste bioconversion process. The BSF life cycle consists of five developmental stages: egg, larva, prepupa, pupa, and adult fly. Among these stages, the larval phase represents the most critical period for waste degradation because larvae consume large quantities of organic materials to accumulate sufficient energy reserves before metamorphosis. This intensive feeding behavior enables rapid decomposition of organic waste while producing substantial larval biomass [26]. After completing the feeding phase, larvae develop into prepupae and pupae before emerging as adult flies. Adult BSF possess non-functional mouthparts and therefore do not feed or transmit pathogens through food contamination, distinguishing them from common houseflies. Integrating the insect life cycle with the waste conversion process provides a comprehensive understanding of why the larval stage serves as the primary biological engine driving BSF-based waste management systems [27]. This illustration also emphasizes that maintaining healthy larval development is essential for achieving maximum waste reduction efficiency and biomass production.

Table 1. Summary of Organic Waste Reduction Efficiency Using BSF Larvae

Organic Waste Type	Waste Reduction Efficiency (%)	Processing Duration	Main Products
Household food waste	75–85	14–18 days	Larval biomass, frass
Traditional market waste	70–82	15–20 days	Larval biomass, frass
Fruit and vegetable waste	70–80	12–16 days	Larval biomass, frass
Agricultural residues	60–75	18–21 days	Larval biomass, frass

Table 1 summarizes the reported efficiency of BSF larvae in processing different categories of organic waste. Although waste characteristics vary considerably among substrates, the literature consistently indicates that BSF larvae achieve high waste reduction efficiencies within relatively short processing periods. Household food waste generally exhibits the highest degradation performance because of its balanced nutritional composition, whereas agricultural residues containing higher proportions of lignocellulosic materials require longer processing times [28]. Despite these differences, all substrate types are capable of producing valuable outputs in the form of protein-rich larvae and nutrient-rich frass. The summarized findings demonstrate that BSF technology possesses considerable flexibility for treating diverse organic waste streams generated from domestic, commercial, and agricultural sectors [29]. Such adaptability supports the implementation of decentralized waste management systems while reducing dependence on landfill disposal. Therefore, BSF bioconversion offers an effective and scalable biological solution capable of addressing heterogeneous organic waste generated across different environmental and socio-economic settings.

Table 2. Characteristics of Organic Waste Suitable for BSF Bioconversion

Organic Waste Category	Nutritional Characteristics	Suitability for BSF	Expected Larval Performance
Rice leftovers	High carbohydrate and moisture	Very High	Rapid growth and high biomass
Meat and fish residues	High protein and lipid	Very High	High protein accumulation
Fruit and vegetable waste	Rich in vitamins and fiber	High	Moderate to high growth
Mixed household organic waste	Balanced nutrient composition	High	Stable larval development

Table 2 presents the characteristics of organic waste materials that are considered suitable substrates for BSF bioconversion. Substrate composition plays a crucial role in determining larval growth rate, waste conversion efficiency, and the nutritional quality of the harvested biomass. Organic waste containing balanced levels of carbohydrates, proteins, lipids, and moisture generally provides favorable conditions for larval development [30]. Rice leftovers and protein-rich food residues have been reported to support the highest biomass production because they supply sufficient energy and amino acids required for rapid growth. Conversely, substrates containing excessive fiber or insufficient moisture may reduce feeding efficiency and prolong the conversion process. Understanding substrate characteristics is therefore essential for optimizing BSF production systems and ensuring consistent operational performance [31]. Appropriate substrate selection not only improves waste reduction efficiency but also enhances the quality of larval biomass and frass, thereby maximizing the environmental and economic benefits generated through BSF-based organic waste management.

b. Environmental and Operational Performance of BSF-Based Organic Waste Management

The successful implementation of Black Soldier Fly (BSF) bioconversion depends not only on the biological ability of larvae to degrade organic waste but also on environmental conditions and operational management throughout the production process. Numerous studies indicate that environmental parameters, substrate quality, and cultivation practices collectively influence waste reduction efficiency, larval growth, biomass production, and the quality of the resulting products [32]. Consequently, BSF bioconversion should be regarded as an integrated waste management system in which biological and operational factors work together to maximize environmental performance.

Among the environmental variables affecting BSF cultivation, temperature is considered one of the most influential factors because it directly regulates larval metabolism and feeding activity. Previous studies have reported that BSF larvae perform optimally at temperatures ranging from 25°C to 35°C, where rapid growth and efficient waste degradation can be achieved [33]. Temperatures below this range slow larval development, whereas excessively high temperatures may increase mortality and reduce feeding efficiency. In addition to temperature, substrate moisture content significantly affects larval mobility and decomposition performance. Moisture levels between 60% and 70% are generally recommended because they provide favorable conditions for larval feeding while minimizing anaerobic fermentation and unpleasant odors [34]. Maintaining these environmental conditions is therefore essential for achieving stable bioconversion performance.

The composition of the organic substrate also plays a critical role in determining operational efficiency. Organic waste containing balanced proportions of carbohydrates, proteins, lipids, and moisture generally supports faster larval growth and higher biomass production than substrates dominated by fibrous materials [24], [35]. Proper waste segregation before processing is equally important because contamination by plastics, metals, glass, or hazardous materials can reduce larval performance and negatively affect the quality of harvested biomass and frass. Therefore, source-level waste separation represents a fundamental operational requirement for successful BSF implementation.

Besides substrate quality, several operational factors contribute to the effectiveness of the bioconversion process. Appropriate larval density ensures efficient utilization of available organic waste without creating excessive competition for food resources. Adequate aeration maintains aerobic conditions during decomposition and helps prevent odor generation, while regular monitoring of moisture and feeding schedules improves larval growth consistency [36]. Harvesting larvae at the late larval or prepupal stage is also important because nutritional quality declines as metamorphosis progresses. These operational practices demonstrate that successful BSF cultivation requires systematic management throughout the production cycle.

From an environmental perspective, BSF bioconversion offers several advantages over conventional organic waste treatment methods. The rapid degradation of biodegradable waste substantially reduces the amount of waste transported to landfills, thereby lowering methane emissions associated with anaerobic decomposition [37]. Unlike the common housefly (*Musca domestica*), adult BSF do not possess functional mouthparts and are not considered vectors of human diseases [38]. In addition, the residual material produced during the bioconversion process, commonly known as frass, is rich in organic matter, nutrients, and beneficial microorganisms that improve soil fertility and support sustainable agriculture [39]. These characteristics demonstrate that BSF bioconversion not only enhances waste reduction efficiency but also promotes resource recovery and environmental sustainability. Overall, the reviewed literature confirms that maintaining optimal environmental conditions together with standardized operational management is fundamental for maximizing the environmental and economic benefits of BSF-based organic waste management.

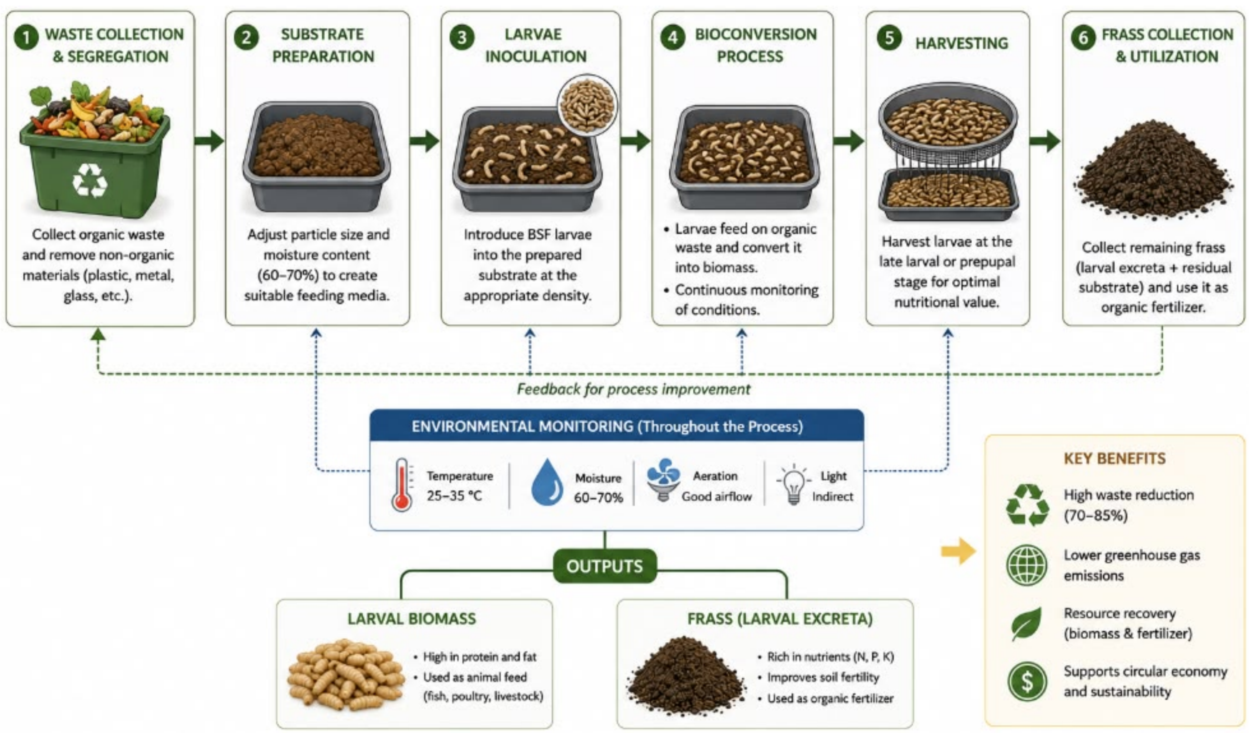

Figure 5. Operational Framework of BSF-Based Organic Waste Management

Figure 5 illustrates the operational workflow required to achieve efficient organic waste management through BSF bioconversion. The framework begins with waste collection and segregation, where biodegradable materials are separated from inorganic contaminants to ensure substrate quality. The prepared substrate is then conditioned to achieve appropriate moisture content before BSF larvae are introduced for feeding [40]. During the bioconversion stage, larvae actively consume organic waste while simultaneously converting nutrients into larval biomass and reducing waste volume. Environmental monitoring, including temperature, humidity, and aeration, is maintained throughout the process to optimize larval performance. Once larvae reach the late larval or prepupal stage, harvesting is conducted to obtain protein-rich biomass, while the remaining frass is collected as organic fertilizer. The framework emphasizes that successful BSF implementation relies on a continuous sequence of operational activities rather than isolated waste treatment steps [41]. Proper management at every stage contributes to higher waste reduction efficiency, improved product quality, and enhanced environmental sustainability. This operational framework also serves as a practical guideline for scaling BSF technology from household applications to municipal and industrial waste management systems.

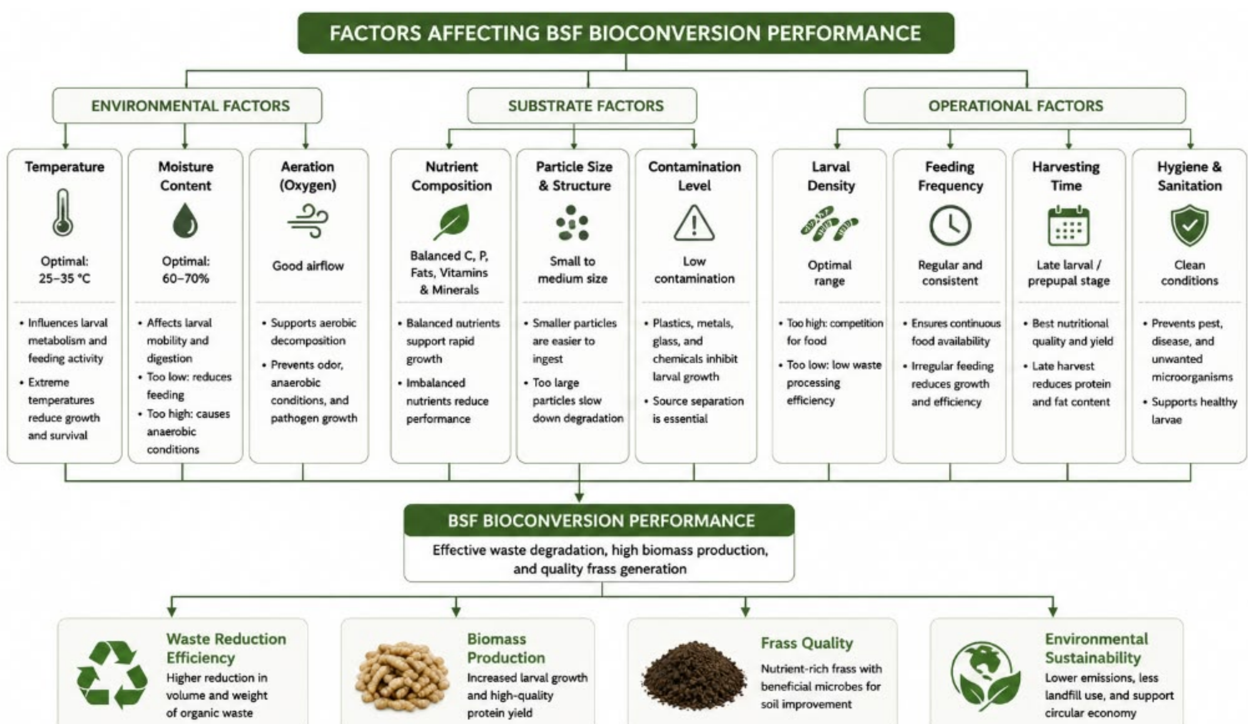

Figure 6. Factors Affecting BSF Bioconversion Performance

Figure 6 summarizes the major environmental and operational factors influencing the efficiency of BSF bioconversion. Environmental variables such as temperature, substrate moisture, aeration, and light exposure directly regulate larval metabolism, feeding behavior, and growth performance. At the same time, substrate characteristics including nutrient composition, particle size, and contamination level strongly affect feed conversion efficiency and biomass production [42]. Operational factors, such as larval density, feeding frequency, harvesting schedule, and facility sanitation, further determine the stability of the production process. The figure illustrates that these variables interact with one another rather than acting independently, highlighting the need for integrated management to achieve optimal bioconversion outcomes. Failure to maintain favorable environmental conditions or operational standards may reduce waste degradation efficiency, prolong larval development, and decrease biomass quality [43]. Consequently, successful BSF cultivation requires continuous monitoring and adaptive management to maintain balanced environmental conditions throughout the production cycle while ensuring sustainable waste processing performance.

Table 3. Environmental Requirements for Optimal BSF Cultivation

Environmental Factor	Recommended Condition	Effect on BSF Performance	Operational Implication
Temperature	25–35°C	Maximizes metabolism and feeding activity	Maintain stable environmental temperature
Moisture Content	60–70%	Supports efficient waste decomposition	Adjust substrate moisture regularly
Aeration	Good air circulation	Prevents anaerobic decomposition and odor	Provide adequate ventilation
Light Exposure	Indirect or shaded	Reduces larval stress and promotes feeding	Protect rearing units from direct sunlight

Table 3 summarizes the principal environmental conditions required for successful BSF cultivation. Temperature, moisture content, aeration, and light exposure collectively influence larval physiology, feeding activity, and waste conversion efficiency. Maintaining temperatures within the optimal range promotes rapid larval development, whereas excessive or insufficient temperatures reduce metabolic performance [44]. Similarly, appropriate moisture content enhances larval mobility and microbial activity while preventing excessive fermentation. Adequate aeration maintains aerobic decomposition and minimizes odor formation, contributing to a healthier production environment. Because BSF larvae naturally avoid direct sunlight, shaded conditions further improve feeding behavior and reduce environmental stress. The information presented in this table provides practical guidance for researchers, farmers, and waste management practitioners seeking to optimize BSF production systems under different climatic and operational conditions [45]. Maintaining these environmental parameters consistently is fundamental to achieving high biomass productivity, efficient waste reduction, and stable frass quality.

Table 4. Environmental Benefits of BSF Bioconversion Compared with Conventional Composting

Environmental Aspect	Conventional Composting	BSF Bioconversion	Environmental Advantage
Processing Time	Several weeks to months	Approximately 2–3 weeks	Faster waste stabilization
Waste Volume Reduction	Moderate	High (70–85%)	Lower landfill burden
Greenhouse Gas Emissions	Higher methane potential	Lower methane generation	Reduced climate impact
Valuable Outputs	Compost	Larval biomass and frass	Multiple resource recovery products

Table 4 compares the environmental performance of BSF bioconversion with conventional composting methods. Although both technologies recycle organic waste, BSF bioconversion generally provides faster processing times, greater waste reduction efficiency, and higher resource recovery potential. The rapid consumption of organic materials by BSF larvae reduces the duration during which biodegradable waste undergoes uncontrolled decomposition, thereby lowering methane emissions commonly associated with landfill disposal and prolonged composting [46]. Unlike conventional composting, which primarily produces compost, BSF bioconversion generates two economically valuable products: protein-rich larval biomass and nutrient-rich frass. These additional outputs enhance resource utilization while supporting circular economy principles [47]. Furthermore, the shorter processing period enables more efficient waste handling and decreases the space required for treatment facilities. Collectively, these advantages demonstrate that BSF bioconversion represents a more integrated and environmentally sustainable organic waste management strategy capable of simultaneously addressing waste reduction, resource recovery, and climate change mitigation.

c. BSF Bioconversion as an Integrated Strategy for Circular Economy and Sustainable Waste Management

The growing volume of organic waste has encouraged a transition from conventional waste disposal toward circular economy approaches that emphasize resource recovery and sustainable material utilization. Within this context, Black Soldier Fly (BSF) bioconversion has emerged as an innovative biological technology capable of converting biodegradable waste into valuable products while minimizing environmental impacts [48]. Rather than functioning solely as a waste treatment method, BSF bioconversion integrates waste reduction, nutrient recovery, alternative protein production, and organic fertilizer generation into a single sustainable management system.

One of the main strengths of BSF technology is its ability to establish a closed-loop resource recovery system. Organic waste from households, food industries, restaurants, traditional markets, and agricultural activities is utilized as the primary substrate for larval growth. During the bioconversion process, BSF larvae convert organic materials into protein-rich biomass while significantly reducing waste volume [49]. The harvested larvae can be used as an alternative protein source for aquaculture, poultry, and livestock production, whereas the remaining frass serves as nutrient-rich organic fertilizer that supports soil fertility and sustainable crop production. This continuous transformation of waste into valuable resources reflects the fundamental principles of a circular economy by minimizing waste disposal and maximizing resource utilization.

BSF bioconversion also provides substantial environmental and economic benefits. Reducing the amount of biodegradable waste sent to landfills lowers methane emissions associated with anaerobic decomposition while extending landfill operational capacity. At the same time, the production of insect-based protein decreases dependence on conventional feed ingredients such as fish meal and soybean meal, whereas frass contributes to sustainable agriculture by reducing the need for synthetic fertilizers [50]. These integrated benefits support several Sustainable Development Goals (SDGs), particularly those related to responsible consumption and production, climate action, food security, and sustainable cities.

From an economic perspective, BSF technology creates multiple value-added products from materials that previously possessed little economic value. Larval biomass and frass provide new business opportunities for communities, farmers, and private industries while simultaneously reducing waste transportation and disposal costs. However, the long-term success of BSF implementation depends on collaboration among governments, academic institutions, private sectors, and local communities [51]. Government policies promoting waste segregation and circular economy initiatives, combined with continuous technological innovation and community participation, are essential for scaling up BSF-based waste management systems.

Overall, the reviewed literature demonstrates that BSF bioconversion represents an integrated strategy that connects waste management, biological resource recovery, agricultural sustainability, and circular economy implementation within a unified environmental management framework. This integrated perspective extends beyond conventional waste treatment by positioning organic waste as a renewable resource capable of generating environmental, economic, and social benefits [52]. Consequently, BSF bioconversion provides a comprehensive approach for supporting sustainable organic waste management while strengthening the transition toward a circular and resource-efficient economy.

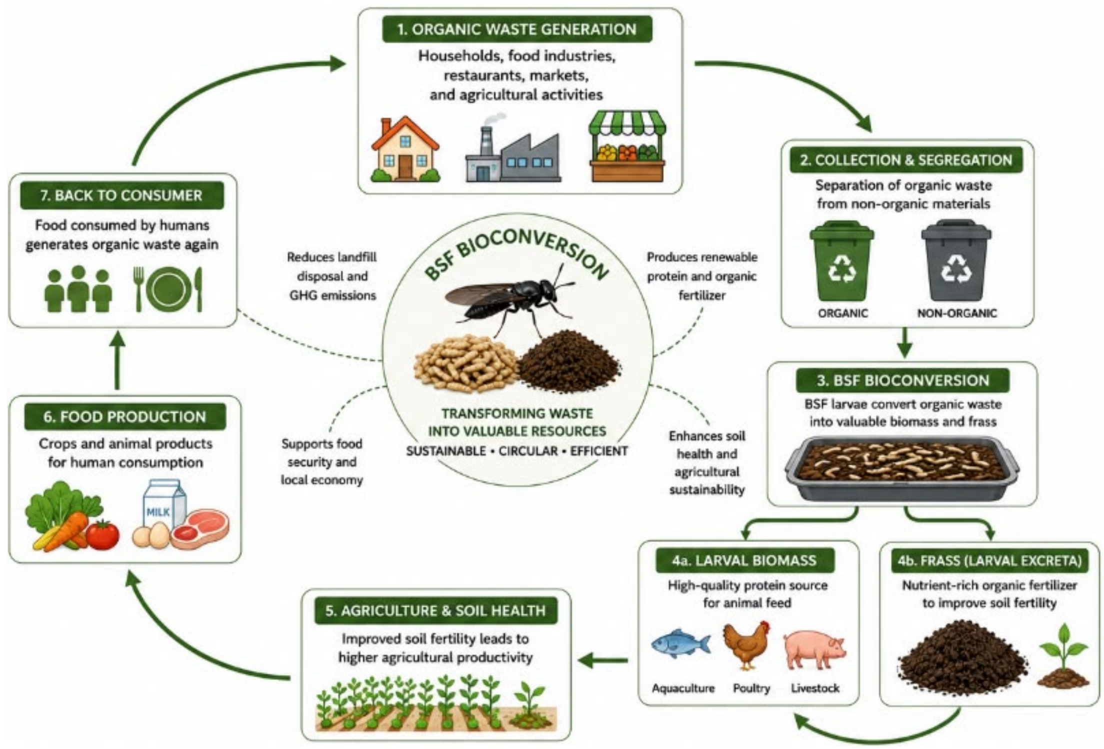

Figure 7. Circular Economy Framework of BSF-Based Organic Waste Management

Figure 7 illustrates the application of circular economy principles through BSF-based organic waste management. The framework demonstrates how organic waste generated from households, food industries, restaurants, markets, and agricultural activities is redirected from landfill disposal into a biological conversion process using BSF larvae. During bioconversion, organic waste is transformed into two valuable products: protein-rich larval biomass and nutrient-rich frass [53]. Larval biomass subsequently enters livestock, poultry, and aquaculture production systems as an alternative feed source, whereas frass is utilized as organic fertilizer to improve soil fertility and support crop cultivation. Agricultural products generated from these systems ultimately become food resources for human consumption, which in turn produce new organic waste, completing the circular resource cycle. This figure emphasizes that BSF bioconversion minimizes waste generation while maximizing resource recovery, thereby reducing environmental pollution and dependence on virgin natural resources [54]. The framework highlights the transition from the traditional linear economy model of "take–make–dispose" toward a regenerative circular economy that continuously recycles biological resources through sustainable production and consumption systems.

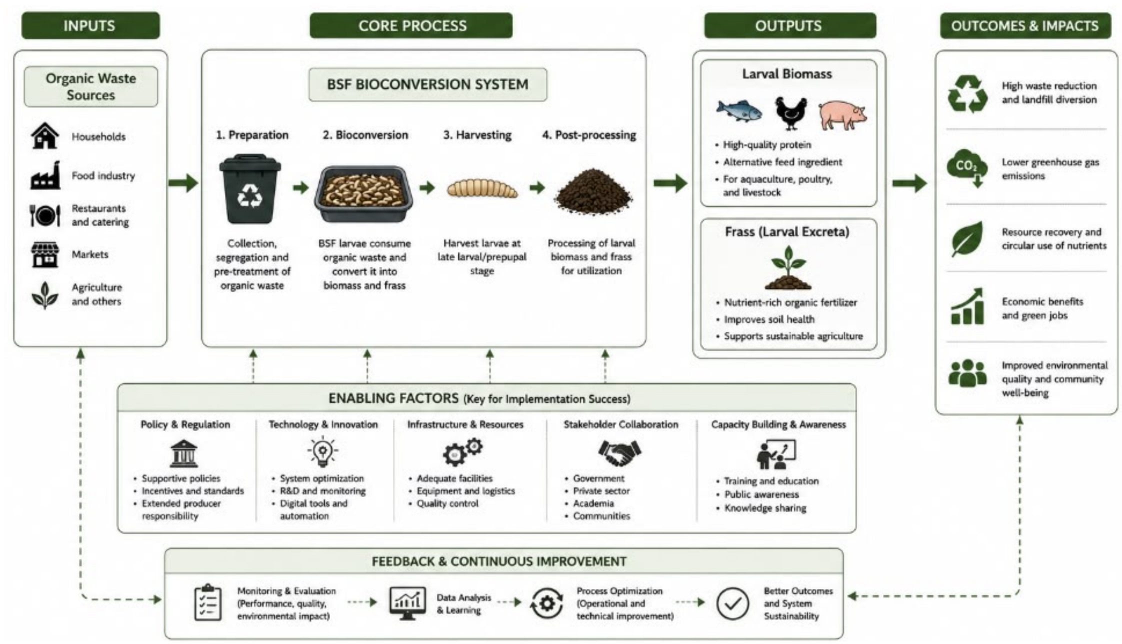

Figure 8. Integrated Conceptual Framework for Sustainable Organic Waste Management

Figure 8 presents the integrated conceptual framework developed from the synthesis of previous scientific literature. The framework positions BSF bioconversion as the central mechanism linking biological processes, operational management, environmental sustainability, and circular economy implementation. Organic waste serves as the primary input, while environmental factors and operational practices regulate the efficiency of biological conversion [55]. The resulting outputs, including larval biomass and frass, generate environmental, economic, and agricultural benefits through resource recovery and waste valorization. These interconnected components collectively contribute to sustainable organic waste management by reducing landfill dependence, mitigating greenhouse gas emissions, supporting renewable feed production, improving soil fertility, and strengthening circular economy practices[56]. Unlike previous studies that typically discuss these aspects separately, the proposed framework integrates biological, operational, environmental, and socio-economic dimensions into a unified model [57]. Consequently, this conceptual framework represents the principal novelty of the present review and provides a theoretical foundation for future research, policy development, and practical implementation of BSF technology within sustainable waste management systems.

Table 5. Economic Value Generated from BSF Bioconversion

BSF Product	Potential Utilization	Economic Contribution	Beneficiary Sector
Fresh Larval Biomass	Aquaculture, poultry, livestock feed	Reduces feed production costs	Livestock and aquaculture industries
Dried BSF Meal	Commercial protein ingredient	Higher market value and wider distribution	Feed manufacturing companies
Frass	Organic fertilizer	Increases agricultural productivity and fertilizer sales	Agriculture sector
Organic Waste Processing Service	Community-based waste management	Reduces waste disposal costs and creates employment	Local governments and communities

Table 5 summarizes the major economic values generated through BSF bioconversion. Unlike conventional waste management systems that primarily focus on waste disposal, BSF technology creates multiple marketable products from biodegradable waste streams. Protein-rich larval biomass represents the highest-value product because of its increasing demand as an alternative feed ingredient for aquaculture and livestock industries [58]. Drying and processing larvae into insect meal further increase product value by improving storage stability and transportation efficiency. Frass contributes additional economic benefits by serving as an organic fertilizer capable of improving soil fertility while reducing dependence on synthetic fertilizers. Beyond product sales, BSF implementation generates indirect economic benefits through reduced waste transportation costs, lower landfill expenditures, and employment opportunities associated with insect farming and waste processing [59], [60]. Collectively, these economic values demonstrate that BSF bioconversion transforms organic waste into productive biological resources that support sustainable business development and local economic resilience.

Table 6. Strategic Recommendations for Sustainable BSF Implementation

Stakeholder	Strategic Recommendation	Expected Outcome	Implementation Priority
Government	Strengthen waste segregation policies, incentives, and technical regulations	Improved waste quality and wider BSF adoption	High
Academic Institutions	Conduct research, technology development, and capacity building	Increased innovation and operational efficiency	High
Private Sector	Invest in BSF production facilities and commercialization	Market expansion and economic growth	Medium–High
Local Communities	Implement household waste segregation and community-scale BSF cultivation	Sustainable decentralized waste management	High

Table 6 presents strategic recommendations for supporting sustainable BSF implementation through multi-stakeholder collaboration. The successful expansion of BSF technology requires coordinated actions among governments, research institutions, private industries, and local communities [61]. Governments play a leading role by establishing supportive regulations, promoting waste segregation, and providing incentives for sustainable waste management initiatives. Academic institutions contribute through scientific research, technological innovation, and technical training that improve operational efficiency and product quality. The private sector facilitates investment, commercialization, and market development, thereby increasing the economic feasibility of BSF enterprises [62]. Meanwhile, local communities remain the foundation of decentralized implementation through consistent waste segregation and community-based BSF cultivation. Integrating these strategic actions creates a comprehensive governance framework capable of accelerating the transition toward sustainable organic waste management [63]. The recommendations summarized in this table provide practical guidance for policymakers and practitioners seeking to implement BSF technology as part of national circular economy and environmental sustainability strategies.

Conclusion

This literature review demonstrates that Black Soldier Fly (BSF) bioconversion represents an effective and integrated approach for optimizing organic waste management while supporting the transition toward a circular economy and sustainable resource utilization. The synthesis of previous scientific studies consistently indicates that BSF larvae possess a remarkable capacity to reduce organic waste volume rapidly through efficient biological decomposition, transforming biodegradable materials into two valuable products: protein-rich larval biomass and nutrient-rich frass. Beyond its technical capability in waste reduction, BSF bioconversion contributes significantly to resource recovery by producing alternative animal feed and organic fertilizer, thereby enhancing both environmental and economic value.

The findings further reveal that the performance of BSF bioconversion is strongly influenced by environmental and operational factors, including temperature, substrate moisture, waste composition, aeration, larval density, and harvesting management. Maintaining optimal cultivation conditions and implementing standardized operational procedures are essential for maximizing waste reduction efficiency, biomass productivity, and frass quality. These findings emphasize that successful BSF implementation requires not only biological efficiency but also systematic environmental management and appropriate operational practices.

From a broader sustainability perspective, BSF bioconversion offers multiple benefits that extend beyond conventional waste treatment. By reducing landfill dependency, mitigating greenhouse gas emissions, recovering nutrients, and creating value-added products from organic waste, BSF technology directly supports the principles of the circular economy and several Sustainable Development Goals (SDGs), particularly those related to responsible consumption and production, climate action, sustainable cities, and food security. Furthermore, the integration of waste management with livestock production and sustainable agriculture demonstrates the potential of BSF bioconversion to establish a regenerative resource cycle that simultaneously generates environmental, economic, and social benefits.

The principal contribution of this review lies in the development of an integrated conceptual framework that synthesizes biological mechanisms, environmental and operational factors, resource recovery processes, and circular economy principles into a unified perspective for sustainable organic waste management. Unlike previous studies that primarily discuss these dimensions independently, this review provides a comprehensive framework that explains the interrelationships among technical performance, environmental sustainability, and socio-economic value creation. This integrated perspective offers a stronger theoretical foundation for understanding the role of BSF bioconversion within modern waste management systems.

Future research should focus on validating the proposed conceptual framework through field-scale implementation and quantitative assessment under diverse environmental and socio-economic conditions. Additional studies are also recommended to evaluate long-term environmental impacts, life cycle assessment (LCA), techno-economic feasibility, greenhouse gas mitigation potential, and policy integration to support wider adoption of BSF technology. Such efforts will strengthen the scientific evidence required to position BSF bioconversion as a key component of sustainable organic waste management strategies and circular economy development at local, national, and global levels.

Reference

[1] N. Miguel, A. López, S. D. Jojoa-Sierra, J. Gómez, and M. P. Ormad, "Sustainable Management of the Organic Fraction of Municipal Solid Waste: Microbiological Quality Control During Composting and Its Application in Agriculture on a Pilot Scale," *Sustainability*, vol. 17, no. 9, p. 4169, May 2025, doi: 10.3390/su17094169.

[2] A. Kupczyk, "Sustainable management of coastal organic waste: A pilot study on beach wrack treatment in reed bed system," *Journal of Ecological Engineering*, vol. 26, no. 6, pp. 202–218, Jun. 2025, doi: 10.12911/22998993/201994.

[3] A. Ghosh *et al.*, "Forecasting organic waste and biomethane generation potential of a non industrial district of Eastern India: A data-driven approach to sustainable energy and waste management," *Cleaner Waste Systems*, vol. 12, p. 100378, Dec. 2025, doi: 10.1016/j.clwas.2025.100378.

[4] L. Rahayu, D. R. Kamardiani, and A. A. Nurusman, "Application of Biopori Technology for Sustainable Management of Household Organic Waste," *BIO Web Conf.*, vol. 137, p. 03013, Nov. 2024, doi: 10.1051/bioconf/202413703013.

[5] L. M. Ulloa-Murillo, L. M. Villegas, A. R. Rodríguez-Ortiz, M. Duque-Acevedo, and F. J. Cortés-García, "Management of the Organic Fraction of Municipal Solid Waste in the Context of a Sustainable and Circular Model: Analysis of Trends in Latin America and the Caribbean," *Int. J. Environ. Res. Public Health*, vol. 19, no. 10, p. 6041, May 2022, doi: 10.3390/ijerph19106041.

[6] A. Thirunavukkarasu *et al.*, "Sustainable organic waste management using vermicomposting: a critical review on the prevailing research gaps and opportunities," *Environ. Sci. Process. Impacts*, vol. 25, no. 3, pp. 364–381, 2023, doi: 10.1039/D2EM00324D.

[7] G. Vinci, R. Ruggieri, A. Billi, C. Pagnozzi, M. V. Di Loreto, and M. Ruggeri, "Sustainable Management of Organic Waste and Recycling for Bioplastics: A LCA Approach for the Italian Case Study," *Sustainability*, vol. 13, no. 11, p. 6385, Jun. 2021, doi: 10.3390/su13116385.

[8] N. F. Amrul *et al.*, "A Review of Organic Waste Treatment Using Black Soldier

Fly (Hermetia illucens),” pp. 1–15, 2022.

[9] R. Bhatt *et al.*, “Vermicomposting for climate change mitigation and sustainable soil health: Organic waste management, nitrogen use efficiency, and ecosystem services,” *SAINS TANAH - Journal of Soil Science and Agroclimatology*, vol. 22, no. 2, p. 525, Dec. 2025, doi: 10.20961/stjssa.v22i2.108669.

[10] H. Lu *et al.*, “Yeast enrichment facilitated lipid removal and bioconversion by black soldier fly larvae in the food waste treatment,” *Waste Management*, vol. 166, pp. 152–162, Jul. 2023, doi: 10.1016/j.wasman.2023.04.003.

[11] S. S. Markam, A. Raj, A. Kumar, and M. L. Khan, “Microbial biosurfactants: Green alternatives and sustainable solution for augmenting pesticide remediation and management of organic waste,” *Curr. Res. Microb. Sci.*, vol. 7, p. 100266, 2024, doi: 10.1016/j.crmicr.2024.100266.

[12] S. Ayyappa, S. Malakannavar, and V. G. Jayaramegowda, “Profiling and Valorization of Urban Organic Wastes for Sustainable Soil Nutrient Management and Maize Production,” *J. Soil Sci. Plant Nutr.*, vol. 26, no. 1, pp. 3112–3130, Mar. 2026, doi: 10.1007/s42729-026-03053-7.

[13] A. Tryhuba *et al.*, “A Data-Driven Risk-Informed Decision Support Framework for Sustainable Municipal Organic Waste Management in Smart Cities,” *Sustainability*, vol. 18, no. 12, p. 5862, Jun. 2026, doi: 10.3390/su18125862.

[14] D. Domínguez-Solís, M. C. Martínez-Rodríguez, L. E. Campos-Villegas, H. G. Ramírez-Escamilla, and X. V. Bello-Yañez, “Sustainable Management of Organic Waste as Substrates in Constructed Wetlands: A Systematic Review,” *Sustainability*, vol. 18, no. 1, p. 318, Dec. 2025, doi: 10.3390/su18010318.

[15] P. Homet, D. Zuazagoitia, L. Alcántara Rubio, L. Morillas, M. T. Domínguez, and M. Gil Martínez, “OrgWASTE: La Ciencia Ciudadana como estrategia educativa para comprender la descomposición de la materia orgánica y promover prácticas sostenibles en la gestión de residuos,” *Ecosistemas*, p. 3084, Feb. 2026, doi: 10.7818/ECOS.3084.

[16] J. Bekier, E. Jamroz, J. Sowiński, K. Adamczewska-Sowińska, M. Wilusz-Nogueira, and D. Gruszka, “Selected Properties of Bioconversion Products of Lignocellulosic Biomass and Biodegradable Municipal Waste as a Method for Sustainable Management of Exogenous Organic Matter,” *Sustainability*, vol. 17, no. 4, p. 1491, Feb. 2025, doi: 10.3390/su17041491.

[17] S. Zarezadeh *et al.*, “Sustainable soil management in agriculture under drought stress: Utilising waste-derived organic soil amendments and beneficial impacts on soil bacterial processes,” *Applied Soil Ecology*, vol. 206, p. 105870, Feb. 2025, doi: 10.1016/j.apsoil.2025.105870.

[18] H. Wang *et al.*, “Precision co-composting of multi-source organic solid wastes provide a sustainable waste management strategy with high eco-efficiency: a life cycle assessment,” *Environmental Science and Pollution Research*, vol. 32, no. 22, pp. 13487–13496, Feb. 2024, doi: 10.1007/s11356-024-32320-2.

[19] M. Xu *et al.*, “Sustainable solutions: Bio-drying for organic solid waste management,” *Ind. Crops Prod.*, vol. 222, p. 119606, Dec. 2024, doi: 10.1016/j.indcrop.2024.119606.

[20] H. R. Kopaei, M. Nooripoor, A. Karami, and M. Ertz, "Modeling consumer home composting intentions for sustainable municipal organic waste management in Iran," *AIMS Environ. Sci.*, vol. 8, no. 1, pp. 1–17, 2021, doi: 10.3934/environsci.2021001.

[21] C. J. Cunningham, T. A. Peshkur, M. S. Kuyukina, and I. B. Ivshina, "Sustainable Bioremediation of Hydrocarbon Contaminated Soils: Opportunities for Symbiosis with Organic Waste Management?," *Russ. J. Ecol.*, vol. 52, no. 6, pp. 463–469, Nov. 2021, doi: 10.1134/S1067413621060047.

[22] H. Zhang *et al.*, "Isolation and characterization of cyromazine-degrading bacteria from soil and its application in bioconversion by black soldier fly," *Environ. Technol. Innov.*, vol. 39, p. 104221, Aug. 2025, doi: 10.1016/j.eti.2025.104221.

[23] S. Vozzo *et al.*, "Bioconversion of expired canned cat food via Black Soldier Fly larvae: a sustainable approach to waste valorisation," *Ital. J. Anim. Sci.*, vol. 24, no. 1, pp. 1437–1448, Dec. 2025, doi: 10.1080/1828051X.2025.2524545.

[24] Y. Zhang *et al.*, "Integrating metabolomics and physicochemical analysis in black soldier fly bioconversion of Schizochytrium residue: A pathway to high-value ω-3 products," *Future Foods*, vol. 12, p. 100759, Dec. 2025, doi: 10.1016/j.fufo.2025.100759.

[25] N. Wu *et al.*, "Black soldier fly larvae bioconversion and subsequent composting promote larval frass quality during pig and chicken manure transformation process," *Bioresour. Technol.*, vol. 402, p. 130777, Jun. 2024, doi: 10.1016/j.biortech.2024.130777.

[26] J. V. Vodounnou *et al.*, "Valorization of Water Lettuce (Pistia stratiotes L.) Through Bioconversion for Black Soldier Fly Larvae (Hermetia illucens): Larvae Growth, Survival Rate, and Nutritional Quality," *Insects*, vol. 16, no. 10, p. 1068, Oct. 2025, doi: 10.3390/insects16101068.

[27] C. Lalander, I. G. Lopes, N. Gyftopoulos, and B. Vinnerås, "The impact of scale and frass recirculation on pathogen inactivation dynamics in black soldier fly larvae bioconversion," *Front. Microbiol.*, vol. 16, Mar. 2025, doi: 10.3389/fmicb.2025.1539486.

[28] Y. El-byari and M. B. Amraoui, "Enhancement of bioconversion of vegetable biowaste by black soldier fly larvae: Influence of mechanical and thermomechanical pretreatments," *Sci. Afr.*, vol. 27, p. e02626, Mar. 2025, doi: 10.1016/j.sciaf.2025.e02626.

[29] A. R. K. Kullan, A. Suresh, H. L. Choi, E. Gabriel Neumann, and F. Hassan, "Bioconversion of Poultry Litter into Insect Meal and Organic Frasstilizer Using Black Soldier Fly Larvae as a Circular Economy Model for the Poultry Industry: A Review," *Insects*, vol. 16, no. 1, p. 12, Dec. 2024, doi: 10.3390/insects16010012.

[30] Y. Yu *et al.*, "Engineering a gut synthetic microbial community to enhance protein bioconversion from organic wastes by black soldier fly larvae," *Bioresour. Technol.*, vol. 456, p. 134927, Sep. 2026, doi: 10.1016/j.biortech.2026.134927.

[31] D. T. Pavlopoulos, E.-A. Papadopoulou, K. M. Kasiotis, and S. A. Haroutounian, "Black Soldier Fly Promoted Bioconversion of Tomato Toxic Plant Biomass to Safe, Functional Animal Feed," *Molecules*, vol. 31, no. 7, p. 1098, Mar. 2026, doi: 10.3390/molecules31071098.

[32] M. Shao *et al.*, “Synergistic bioconversion of organic waste by black soldier fly (Hermetia illucens) larvae and thermophilic cellulose-degrading bacteria,” *Front. Microbiol.*, vol. 14, Jan. 2024, doi: 10.3389/fmicb.2023.1288227.
[33] B. H. Niranjan *et al.*, “Bioconversion and Performance of Black Soldier Fly (Hermetia illucens) in Converting Organic Poultry Waste Materials into High Value Products and Fertilizers,” *Waste Biomass Valorization*, vol. 15, no. 9, pp. 5559–5572, Sep. 2024, doi: 10.1007/s12649-024-02542-z.
[34] B. D. Prasetiyo, Q. Sholihah, Aulanni’am, and H. Riniwati, “Modelling Bioconversion Processes in Hospital Food Waste Management Using Black Soldier Fly Larvae,” *International Journal of Environmental Impacts*, vol. 7, no. 2, pp. 305–317, Jun. 2024, doi: 10.18280/ijei.070215.
[35] G. Alciatore *et al.*, “Preservation of agri-food byproducts by acidification and fermentation in black soldier fly larvae bioconversion,” *Waste Management*, vol. 186, pp. 109–118, Sep. 2024, doi: 10.1016/j.wasman.2024.05.043.
[36] Z. Xu *et al.*, “Microplastics impair black soldier fly bioconversion of pigeon manure: Physiological and transcriptomic insights,” *Int. Biodeterior. Biodegradation*, vol. 205, p. 106181, Sep. 2025, doi: 10.1016/j.ibiod.2025.106181.
[37] L. Broeckx *et al.*, “Macronutrient-Based Predictive Modelling of Bioconversion Efficiency in Black Soldier Fly Larvae (Hermetia illucens) Through Artificial Substrates,” *Insects*, vol. 16, no. 1, p. 77, Jan. 2025, doi: 10.3390/insects16010077.
[38] A. A. Bedasa and M. H. Habtegebriel, “Black soldier fly Hermetia illucens larvae in organic waste bioconversion current applications economic opportunities and environmental benefits,” *Discover Environment*, vol. 4, no. 1, p. 390, Jul. 2026, doi: 10.1007/s44274-026-00927-6.
[39] K. Pahlavanyali *et al.*, “Valorization of Waste Milk and Dairy Manure Through Black Soldier Fly Larval Bioconversion,” *Waste Biomass Valorization*, Apr. 2026, doi: 10.1007/s12649-026-03616-w.
[40] R. Ursada, A. Y. Bagastyo, C. Y. Tay, A. Purnomo, and I. D. A. A. Warmadewanthi, “Bioconversion of sludge waste by black soldier fly (Hermetia illucens) larvae: A review of the potential use of food and beverage industry sludge as a rearing substrate,” *Cleaner Waste Systems*, vol. 14, p. 100500, Jun. 2026, doi: 10.1016/j.clwas.2026.100500.
[41] N. Kharel *et al.*, “Density and substrate-dependent performance of black soldier fly larvae, Hermetia illucens (Diptera: Stratiomyidae) reared on locally available biowastes in Nepal: Effects on growth, bioconversion, and nutritional composition,” *Cleaner Waste Systems*, vol. 13, p. 100482, Mar. 2026, doi: 10.1016/j.clwas.2026.100482.
[42] J.-S. Chou, B. Phakdee, Z.-T. Lin, C.-P. Yu, P.-H. Wu, and C. Shih, “Automated computer vision monitoring of black soldier fly larval growth using metaheuristic optimization for waste-to-feed bioconversion,” *Comput. Electron. Agric.*, vol. 248, p. 111679, Jul. 2026, doi: 10.1016/j.compag.2026.111679.
[43] H. Su *et al.*, “The Valorization of Food Waste into High-Value Biomass and Organic Fertilizers Through Bioconversion Using Black Soldier Fly Larvae (Hermetia illucens),” *Recycling*, vol. 11, no. 1, p. 8, Jan. 2026, doi: 10.3390/recycling11010008.

[44] Y. A. Y. Abdellah *et al.*, "Bioconversion to bioresources: Pollutant detoxification mechanisms and circular bioeconomy prospects in black soldier fly larvae composting," *Environ. Technol. Innov.*, vol. 42, p. 104878, Jun. 2026, doi: 10.1016/j.eti.2026.104878.

[45] M. M. Mortula, A. Ahmed, K. P. Fattah, G. Zannerni, S. A. Shah, and A. M. Sharaby, "Sustainable Management of Organic Wastes in Sharjah, UAE through Co-Composting," *Methods Protoc.*, vol. 3, no. 4, p. 76, Nov. 2020, doi: 10.3390/mps3040076.

[46] R. A. Teixeira, A. M. Nicolau Korres, R. M. Borges, L. L. Rabello, I. C. Ribeiro, and J. R. Bringhenti, "Sustainable Practices for the Organic Waste Management Generated in an Educational Institution Restaurant," 2020, pp. 803–820. doi: 10.1007/978-3-030-15604-6_49.

[47] F. J. Andriamanohiarisoamanana, S. Yasui, T. Yamashiro, V. Ramanoelina, I. Ihara, and K. Umetsu, "Anaerobic co-digestion: a sustainable approach to food processing organic waste management," *J. Mater. Cycles Waste Manag.*, vol. 22, no. 5, pp. 1501–1508, Sep. 2020, doi: 10.1007/s10163-020-01040-3.

[48] R. K. Ganguly and S. K. Chakraborty, "Eco-management of Industrial Organic Wastes Through the Modified Innovative Vermicomposting Process: A Sustainable Approach in Tropical Countries," in *Earthworm Assisted Remediation of Effluents and Wastes*, Singapore: Springer Singapore, 2020, pp. 161–177. doi: 10.1007/978-981-15-4522-1_10.

[49] R. Kumarasamy Sivasamy, K. Kuppamuthu, L. Krishnasamy Nagaraj, S. P. Manikandan, R. Kulandaivel, and J. G. Bastin, "Utilizing Organic Wastes for Probiotic and Bioproduct Development: A Sustainable Approach for Management of Organic Waste," in *Strategies and Tools for Pollutant Mitigation*, Cham: Springer International Publishing, 2022, pp. 3–28. doi: 10.1007/978-3-030-98241-6_1.

[50] P. Boakye *et al.*, "Pyrolysis of municipal food waste: A sustainable potential approach for solid food waste management and organic crop fertilizer production," *Sustainable Environment*, vol. 9, no. 1, Dec. 2023, doi: 10.1080/27658511.2023.2260057.

[51] S. A. Guvem, B. Ozbey-Unal, B. Keskinler, and C. Balcik, "Redefining the waste: Sustainable management of olive mill waste for the recovery of phenolic compounds and organic acids," *Journal of Water Process Engineering*, vol. 68, p. 106343, Dec. 2024, doi: 10.1016/j.jwpe.2024.106343.

[52] J. Wang *et al.*, "Organic waste recycling for green and sustainable nitrogen management of fruit production systems in China," *Agric. Syst.*, vol. 218, p. 103959, Jun. 2024, doi: 10.1016/j.agsy.2024.103959.

[53] S. Naser El Deen *et al.*, "Bioconversion of Different Waste Streams of Animal and Vegetal Origin and Manure by Black Soldier Fly Larvae Hermetia illucens L. (Diptera: Stratiomyidae)," *Insects*, vol. 14, no. 2, p. 204, Feb. 2023, doi: 10.3390/insects14020204.

[54] A. Resconi *et al.*, "Effects of brewery by-products on growth performance, bioconversion efficiency, nutritional profile, and microbiota and mycobiota of black soldier fly larvae," *animal*, vol. 18, no. 9, p. 101288, Sep. 2024, doi: 10.1016/j.animal.2024.101288.

[55] Z. Zhang *et al.*, "Toxic Effects of Industrial Flocculants Addition on Bioconversion of Black Soldier Fly Larvae (Hermetia illucens L.)," *Insects*, vol. 13, no. 8, p. 683, Jul. 2022, doi: 10.3390/insects13080683.

[56] F. Wang *et al.*, "Co-digestion of chicken manure and sewage sludge in black soldier fly larvae bioconversion system: bacterial biodiversity and nutrients quality of residues for biofertilizer application," *Environmental Science and Pollution Research*, vol. 30, no. 57, pp. 119804–119813, Nov. 2023, doi: 10.1007/s11356-023-30717-z.

[57] Z.-C. Zhang, P. Gu, K.-L. Yang, M.-X. Zhao, Z.-X. Huang, and H.-F. Miao, "Bioconversion of cyanobacteria by black soldier fly larvae (Hermetia illucens L.): Enhancement by antioxidants," *Science of The Total Environment*, vol. 822, p. 153524, May 2022, doi: 10.1016/j.scitotenv.2022.153524.

[58] N. Wu, X. Wang, Z. Mao, J. Liang, X. Liu, and X. Xu, "Bioconversion of chicken meat and bone meal by black soldier fly larvae: Effects of straw addition on the quality and microbial profile of larval frass," *J. Environ. Manage.*, vol. 307, p. 114579, Apr. 2022, doi: 10.1016/j.jenvman.2022.114579.

[59] G. Arabzadeh *et al.*, "Diet Composition Influences Growth Performance, Bioconversion of Black Soldier Fly Larvae: Agronomic Value and In Vitro Biofungicidal Activity of Derived Frass," *Agronomy*, vol. 12, no. 8, p. 1765, Jul. 2022, doi: 10.3390/agronomy12081765.

[60] K. Bohm, G. A. Hatley, B. H. Robinson, and M. J. Gutiérrez-Ginés, "Black Soldier Fly-based bioconversion of biosolids creates high-value products with low heavy metal concentrations," *Resour. Conserv. Recycl.*, vol. 180, p. 106149, May 2022, doi: 10.1016/j.resconrec.2021.106149.

[61] T. C. Nathaniela, A. Pramono, S. A. Nurwardani, A. L. Gunawan, and M. D. Adhirajasa, "Manage Waste organic with Bioconversion Black Soldier Fly on Business Mega Maggot," *E3S Web of Conferences*, vol. 444, p. 04036, Nov. 2023, doi: 10.1051/e3sconf/202344404036.

[62] U. Julita, L. L. Fitri, and A. D. Permana, "Bioconversion efficiencies of several food waste by black soldier fly, Hermetia illucens (L.) (diptera: Stratiomyidae) larvae for sustainable waste management," 2023, p. 020011. doi: 10.1063/5.0129600.

[63] S. Sakiroh, K. D. Sasmita, N. K. Firdaus, D. N. Rokhmah, D. Pranowo, and S. Saefudin, "The effectiveness of liquid biofertilizer from waste bioconversion using black soldier fly larvae on the growth of arabica coffee seedlings," *E3S Web of Conferences*, vol. 373, p. 04022, Mar. 2023, doi: 10.1051/e3sconf/202337304022.