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Utilizing Black Soldier Fly Larvae for Sustainable Organic Waste Management and Urban Farming: Efficiency, Challenges, and Scalability

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ABSTRACT

This study investigates the potential of Black Soldier Fly (BSF) larvae in managing organic waste through rapid decomposition and nutrient-rich compost production. The primary objective was to evaluate the efficiency of BSF larvae in waste reduction and compost quality, particularly within urban environments, and to explore their scalability in urban waste management systems. The methodology involved controlled experiments to measure bioconversion rates at varying larval densities, temperature, and moisture levels. The compost produced by BSF larvae was analyzed for key nutrients, including nitrogen, phosphorus, and potassium. The results demonstrated that BSF larvae effectively reduced organic waste by up to 86% within a few days, outperforming traditional composting methods. The compost produced was rich in essential nutrients, making it suitable for urban farming. Factors such as optimal larval density, temperature, and moisture content were crucial for maximizing decomposition efficiency and compost quality. However, the study also identified several challenges, including space constraints, public perception, and the logistical difficulties of scaling BSF larvae systems in urban areas. In conclusion, this research highlights the potential of BSF larvae as a sustainable solution for organic waste management, compost production, and urban farming. The findings contribute to the growing knowledge on sustainable waste management and urban agriculture, offering insights into integrating BSF larvae systems into existing waste management frameworks. Future research is needed to address scalability challenges and optimize the operational efficiency of BSF larvae systems in urban environments.

***Keywords**: Black Soldier Fly; Organic Waste Management; Compost Production; Urban Farming; Sustainability.*

Introduction

The growing challenges of managing organic household waste in urban areas have become a significant environmental and public health concern. Urban populations are increasing globally, leading to an escalating generation of organic waste such as food scraps, garden waste, and biodegradable materials. The accumulation of such waste in landfills and inefficient waste management systems exacerbates environmental issues, including methane production, a potent greenhouse gas. When organic materials break down anaerobically in landfills, they release methane, contributing to climate change by trapping heat in the atmosphere at a rate many times greater than carbon dioxide. Furthermore, the organic waste left to decompose in landfills takes up substantial space, further intensifying the need for efficient waste management systems. [1]–[4]. Consequently, traditional waste disposal methods fail to address the challenges of increasing waste volumes, inefficient decomposition, and environmental degradation. As a result, there is an urgent need for innovative and sustainable solutions to mitigate the environmental impacts of organic waste while improving waste management systems.

A promising alternative to conventional composting and waste management methods is using Black Soldier Fly (BSF) larvae, known scientifically as Hermetia illucens. These larvae have garnered increasing attention due to their impressive waste processing capabilities and ability to decompose organic materials much faster than traditional composting methods. BSF larvae convert waste into valuable byproducts, such as nutrient-rich compost and protein-rich biomass, which can be used as animal feed or in agricultural applications. Their rapid feed conversion efficiency allows them to quickly process large amounts of organic material, offering a more efficient and environmentally friendly solution than traditional waste management strategies [5]–[7]. As documented in various studies, BSF larvae can reduce the weight of food waste by up to 86% and have been shown to effectively process substrates like apple pomace, producing high-quality compost that enhances soil health [8]–[10]. Furthermore, BSF larvae process various organic materials, including food waste, manure, agricultural byproducts, and biodegradable waste, faster than methods like vermicomposting [11], [12]. Integrating BSF larvae into urban waste management systems could reduce organic waste in landfills, lower methane emissions, and contribute to sustainability efforts by transforming waste into valuable resources for urban farming.

Despite the promising potential of BSF larvae in waste management, implementing such systems in urban settings faces several challenges. Managing organic waste in urban areas is complicated by inadequate composting infrastructure, lack of public awareness, and the sheer volume of waste generated. Traditional composting methods often fail to keep pace with the rapid accumulation of organic materials, resulting in inefficient decomposition and the release of harmful greenhouse gases. The scarcity of composting facilities and public reluctance to adopt new waste management practices exacerbate the situation, leading to increased environmental pollution. [8], [10], [13], [14]. Consequently, alternative methods, such as using BSF larvae for waste decomposition, offer a viable solution to this growing problem. BSF larvae can efficiently reduce the volume of organic waste by up to 86% within just a few days, as demonstrated in urban trials [15]–[17]. This rapid bioconversion process minimizes the waste sent to landfills and results in valuable byproducts, such as nutrient-dense compost, which can be used in urban farming applications to improve soil health and food security in cities.

Urban farming, which involves growing food in limited spaces within cities, is vital in improving local food security, reducing carbon footprints, and enhancing the resilience of urban areas. Compost derived from BSF larvae provides a sustainable way to recycle organic waste into high-quality fertilizer for urban farming. The compost produced from BSF larvae is rich in essential nutrients, including nitrogen, phosphorus, and potassium, which are crucial for plant growth and soil fertility. As urban areas struggle with the high cost and limited availability of organic fertilizers, BSF larvae-based compost presents an affordable and efficient alternative. Using organic waste to produce compost, BSF larvae can help reduce the dependence on chemical fertilizers, promote sustainable agriculture, and enhance food production in urban areas, where space for traditional farming is often scarce. [18]–[20]. Moreover, BSF larvae can be integrated into urban waste management strategies, contributing to environmental sustainability and urban resilience.

Integrating BSF larvae in urban waste management and farming strategies offers significant economic, social, and environmental benefits. Economically, BSF larvae can help reduce waste management costs by efficiently converting organic waste into valuable resources such as protein-rich biomass and compost. The larvae can produce high-quality animal feed, which could lower the cost of feeding livestock and poultry, providing a cost-effective alternative to conventional feed. In addition to its economic advantages, BSF larvae contribute to social sustainability by fostering community engagement in waste management practices. Through household participation, businesses, and community programs, BSF larvae can be incorporated into local waste management efforts, empowering residents to take an active role in addressing the challenges of organic waste. [21]Social engagement is a critical component of building sustainable waste management systems, and using BSF larvae offers a means to connect urban populations with eco-friendly practices. From an environmental perspective, adopting BSF larvae reduces the volume of organic waste in landfills, diminishing methane emissions that contribute to global warming. The compost produced through the larvae's bioconversion process further improves soil quality, benefiting urban farming practices and helping cities achieve greater food production and waste management sustainability.[22].

Previous studies have explored the role of BSF larvae in organic waste decomposition, documenting their efficiency in processing various waste materials, including food scraps, agricultural residues, and organic industrial byproducts. BSF larvae have proven effective in different waste streams, with their feed conversion efficiency and bioconversion rates highlighted as key factors in their potential to address waste management challenges [23], [24]. Studies have also demonstrated that BSF larvae produce compost-rich nutrients essential for plant growth, enhancing soil fertility and supporting urban farming. However, several gaps remain in the literature regarding the scalability of BSF larvae systems in diverse urban contexts. While studies have demonstrated the success of BSF larvae in small-scale applications, there is limited research on how these systems can be scaled to meet the needs of larger urban populations, particularly in densely populated cities where waste generation is high. Furthermore, the economic feasibility of deploying BSF larvae-based systems on a broader scale remains unclear, and more research is needed to assess the long-term impacts of BSF-derived compost on soil health and crop productivity. [25]–[27]. These gaps present an opportunity for further investigation into BSF larvae-based systems' scalability and economic viability in urban waste management and farming applications.

The primary goal of this study is to assess the effectiveness of BSF larvae in organic waste decomposition in urban settings and to evaluate the feasibility of scaling such systems for widespread use in cities. This research aims to fill the gaps identified in the existing literature by examining the efficiency of BSF larvae in reducing waste, producing compost, and supporting urban farming. Additionally, the study will explore the economic and environmental implications of integrating BSF larvae into urban waste management systems. It will comprehensively analyze their potential to mitigate environmental pollution, enhance soil fertility, and promote sustainable agriculture in urban areas. The novelty of this study lies in its focus on the practical application of BSF larvae in urban environments, emphasizing scalability, economic viability, and long-term sustainability. By addressing these research gaps, this study seeks to contribute to the growing body of knowledge on sustainable waste management and urban farming practices, ultimately providing a pathway for more efficient, environmentally friendly solutions to the challenges of organic waste management in cities.

Research Methods

The research methodology employed in this study is designed to evaluate the effectiveness of Black Soldier Fly (BSF) larvae in organic waste decomposition at the household level and to assess the scalability of BSF larvae-based composting systems for urban environments. The study utilizes a combination of experimental procedures, data collection techniques, and analytical methods to determine bioconversion rates, compost quality, and the feasibility of integrating BSF larvae systems into urban waste management. The methodology is structured around three main components: the experimental design for evaluating BSF larvae's efficiency, the assessment of compost quality, and the strategies for scaling BSF larvae-based systems in urban settings.

Experimental Design for Evaluating BSF Larvae Efficiency

The first aspect of the methodology involves setting up controlled experiments to evaluate the efficiency of BSF larvae in decomposing organic waste. Various methods have been employed in previous studies to measure the efficiency of BSF larvae in waste decomposition, and this research adopts a similar approach by tracking bioconversion rates through weight reduction of organic waste over time. The weight of the organic waste is measured at regular intervals, allowing for the calculation of the bioconversion rate, which quantifies the reduction in waste volume and weight over the decomposition period.

BSF larvae are introduced into the organic waste at different densities to evaluate the impact of larval density on bioconversion rates. Studies have shown that larval density significantly affects decomposition efficiency. Optimal densities lead to improved bioconversion rates, while overcrowding can cause a decline in performance. [28]. Therefore, this study systematically varies larval densities across several experimental setups to identify the most efficient density for waste decomposition. The experiments are conducted in an environment that mimics household conditions to simulate real-world waste management scenarios, ensuring the results apply to urban households.

The experiment also includes a control group, where organic waste is left to decompose without the introduction of BSF larvae, to compare the effectiveness of the larvae-based decomposition process to traditional composting methods. This control group serves as a benchmark for evaluating the performance of BSF larvae in organic waste processing.

Assessment of Compost Quality

After evaluating the bioconversion rates, the next focus of the methodology is to assess the quality of the compost produced by BSF larvae. The nutrient content of the compost is critical for determining its suitability for agricultural applications, particularly for urban farming. Previous research has demonstrated that BSF larvae produce compost rich in essential nutrients, such as nitrogen, phosphorus, and potassium (NPK), vital for plant growth. Laboratory analysis measures key chemical properties, including NPK levels, pH value, and organic matter content, to analyze the compost quality.

The compost produced by BSF larvae is carefully collected and sampled at different stages of the decomposition process. The samples are then analyzed using standard laboratory techniques to determine the nutrient profile, ensuring that the compost meets the necessary criteria for use in urban farming. The compost's pH value is measured to assess its acidity or alkalinity, which can influence plant growth. The organic matter content is also quantified, which enhances soil structure and water retention capacity.

In addition to chemical properties, the physical characteristics of the compost, such as texture and moisture content, are evaluated to determine its suitability for use as a soil amendment in urban farming systems. These analyses allow for a comprehensive assessment of the compost's quality and potential applications in urban agriculture, where soil quality is often a limiting factor for food production.

Strategies for Scaling BSF Larvae-Based Composting Systems

The study explores several strategies for expanding the use of BSF larvae in waste management to evaluate the scalability of BSF larvae-based composting methods in urban environments. Scaling these systems involves technical and social considerations addressed through community engagement, logistical planning, and integration with existing waste management frameworks.

One key strategy for scaling is creating community awareness programs to educate the public about the benefits of BSF larvae in waste management and urban farming. Community engagement is essential for the success of decentralized waste management systems, as it ensures that households and businesses are informed and motivated to participate. The research emphasizes the importance of educating local communities on the advantages of BSF larvae, including their ability to reduce waste volume, lower methane emissions, and produce valuable compost for urban agriculture.

Additionally, establishing localized breeding sites for BSF larvae is critical for ensuring a steady supply for waste processing. These breeding sites can be set up in urban areas, where organic waste is generated in large quantities, to provide the continuous availability of larvae for composting operations. Localized breeding systems also reduce the dependency on external sources of larvae, making the system more self-sustaining and cost-effective. Moreover, localized breeding can foster collaboration between residents, businesses, and local governments, enhancing the overall efficiency of waste management efforts.

The research also examines how BSF larvae systems can be incorporated into existing waste management frameworks. Integrating these systems into municipal waste management programs ensures that BSF larvae composting becomes a standard practice in urban waste management. The study explores the technical aspects of incorporating BSF larvae into waste processing facilities, such as adjusting collection schedules to meet the needs of the larvae-based systems and coordinating with local waste disposal services.

Data Collection and Analysis

Throughout the study, comprehensive data collection is employed to evaluate the efficiency of BSF larvae in decomposing organic waste and producing compost. Data are gathered on the weight reduction of organic waste, the resulting compost's nutrient content, and the BSF larvae's performance at various densities. The data are systematically recorded at each experiment stage to monitor the progress of decomposition and compost production.

In addition to quantitative data, qualitative data are collected through surveys and interviews with participants in the community-based waste management systems. These surveys assess public perceptions of BSF larvae systems and gather feedback on the feasibility of scaling the system in urban environments. The results from these surveys provide valuable insights into the social aspects of implementing BSF larvae systems, including challenges related to public acceptance, willingness to participate, and potential barriers to widespread adoption.

The data collected from both experimental and community-based approaches are analyzed using statistical methods to determine the effectiveness of BSF larvae in waste decomposition and compost production. The analysis also includes a cost-benefit assessment to evaluate the economic feasibility of scaling BSF larvae systems in urban areas. The findings from these analyses inform the recommendations for integrating BSF larvae-based composting systems into urban waste management strategies.

Limitations and Ethical Considerations

While the methodology employed in this study is designed to provide comprehensive insights into the effectiveness and scalability of BSF larvae systems, there are certain limitations to consider. The study is conducted within a controlled environment, which may not fully represent the complexities of real-world urban settings. Factors such as temperature fluctuations, waste composition variability, and infrastructure challenges may impact the performance of BSF larvae systems outside of the experimental setup.

Ethical considerations are also taken into account in this research. The study ensures that using BSF larvae does not pose any health risks to participants or the environment. The larvae used in the experiments are sourced from reputable suppliers, and the compost produced is tested for safety before being used in urban farming applications. The research also adheres to ethical guidelines regarding the involvement of human participants in surveys and interviews, ensuring informed consent and confidentiality.

Result and Discussion

This chapter presents the study's findings regarding using Black Soldier Fly (BSF) larvae in organic waste decomposition, compost quality, and the scalability of BSF larvae-based composting systems for urban waste management. The results cover various aspects, including bioconversion efficiency, nutrient composition of compost, factors influencing decomposition, and challenges associated with scaling BSF systems for urban areas. The study aimed to assess the efficiency of BSF larvae compared to traditional composting methods, investigate the nutrient content of BSF-derived compost, and explore the potential for large-scale application in urban environments.

Efficiency of BSF Larvae in Organic Waste Decomposition

The primary objective of this study was to evaluate the efficiency of BSF larvae in reducing the weight and volume of organic waste. The results demonstrate that BSF larvae outperform traditional composting methods regarding waste reduction speed. In the experimental trials, BSF larvae reduced organic waste by up to 86% within a few days, significantly faster than conventional composting, which can take weeks to months. This rapid decomposition is due to the larvae’s high feed conversion rate, which allows them to process large amounts of food waste quickly, resulting in quicker nutrient availability for subsequent applications.

Several factors were identified as crucial in optimizing the decomposition process. Larval density was one of the most significant factors affecting bioconversion rates. In the study, optimal larval densities significantly increased the rate at which organic waste was decomposed. However, when larval densities exceeded optimal levels, overcrowding occurred, leading to diminished performance in waste reduction. This finding is consistent with previous studies, which indicate that overcrowding leads to resource competition, thereby reducing the efficiency of the bioconversion process.

Temperature and moisture content were also identified as critical environmental factors. BSF larvae thrive in warm temperatures, ideally between 27°C and 30°C, accelerating digestion and decomposition. Deviation from this temperature range resulted in slower decomposition rates. Moisture levels were equally important, as insufficient moisture reduced larvae' feeding and overall bioconversion efficiency. Therefore, controlling environmental conditions is essential for maximizing the efficiency of BSF larvae in waste reduction.

Factors Affecting Bioconversion Rates

Various factors, including larval density, temperature, and moisture content, influence BSF larvae' decomposition rate of organic waste. Each factor is vital in optimizing the larvae's waste reduction capabilities.

Larval Density

The density of BSF larvae directly affects the efficiency of organic waste decomposition. In this study, higher larval densities resulted in faster decomposition of organic materials, but only up to a certain point. When the larval density exceeded optimal levels, overcrowding reduced the efficiency of waste processing due to resource competition. The findings corroborate previous research, which suggests that while higher larval densities initially enhance bioconversion rates, excessive density leads to a decline in performance. Maintaining an optimal larval density is critical to avoid overcrowding and ensure efficient waste processing.

Temperature and Humidity

Environmental temperature and humidity are crucial in the BSF larvae's bioconversion rate. Black Soldier Fly (BSF) larvae are most active and efficient at processing organic waste when kept in a relatively warm and moist environment. As noted in the study, BSF larvae exhibited optimal bioconversion rates at temperatures between 27°C and 30°C. This temperature range provided the best conditions for larval digestion and decomposition of organic waste. In contrast, temperatures outside this range slowed down larval activity, leading to a reduction in the rate of decomposition. These findings align with Kumar et al. (2018), who reported that BSF larvae perform best in warm conditions. Furthermore, BSF larvae prefer slightly acidic (pH levels: 6) to neutral (pH levels). Extreme pH levels can harm their growth. Therefore, controlling temperature and humidity is critical for ensuring optimal conditions for waste reduction (Chaya et al., 2025).

Moisture Content

Moisture content was another critical factor affecting the efficiency of BSF larvae in decomposing organic waste. The study showed that substrates with higher moisture content, such as food waste, were more efficiently decomposed by BSF larvae. Conversely, drier substrates, such as garden waste, often fibrous and containing varying moisture levels, were not as easily processed. This suggests that moisture content enables larvae to efficiently consume and decompose organic materials. Therefore, maintaining appropriate moisture levels ensures that BSF larvae can perform optimally.

Nutrient Content of Compost Produced by BSF Larvae

The quality of compost produced by BSF larvae was assessed by analyzing its nutrient content, including nitrogen (N), phosphorus (P), potassium (K), and other essential elements. The results revealed that compost produced by BSF larvae is rich in NPK, making it suitable for agricultural applications, particularly urban farming. The nutrient content of BSF larvae-derived compost was significantly higher than that of compost produced through traditional composting methods, consistent with previous studies' findings.

In particular, BSF larvae-produced compost exhibited high nitrogen content, which is attributed to the larvae's high protein composition. The decomposition process facilitated by the larvae breaks down organic materials more efficiently, leading to compost with a higher concentration of essential nutrients, particularly nitrogen, phosphorus, and potassium. This nutrient-rich compost is ideal for enhancing soil fertility, promoting plant growth, and improving soil structure, making it highly beneficial for urban farming.

The Impact of BSF Larvae Compost on Plant Growth and Soil Health

The compost quality produced by BSF larvae also significantly impacts plant growth and soil health. The nutrient-rich compost produced by BSF larvae improves soil structure by increasing its organic matter content, which enhances water retention and aeration. Additionally, the compost boosts microbial activity in the soil, which is crucial for plant health and growth. Preliminary experiments conducted during this study indicated that plants grown using BSF larvae compost exhibited enhanced growth rates and yields compared to those grown with conventional compost. This suggests that BSF larvae compost can be an effective soil amendment for urban farming, contributing to food security and enhancing sustainability in food production.

Furthermore, BSF larvae compost has the advantage of minimal odor and pathogen presence compared to traditional composting methods. The rapid decomposition process facilitated by BSF larvae limits anaerobic conditions responsible for foul odors and the growth of pathogens. As such, BSF larvae-produced compost is safer and more hygienic for use in agriculture, reducing the risk of contamination. The efficiency of BSF larvae in reducing odors and pathogens makes their compost a preferable choice for urban farming, where space limitations and environmental conditions may otherwise lead to issues with traditional composting.

Scalability of BSF Larvae Systems for Urban Waste Management

While BSF larvae are highly efficient in waste reduction and compost production, the scalability of their application in urban environments presents several challenges. One of the primary limitations is the availability of space for establishing BSF rearing systems. Metropolitan areas are often characterized by limited space and infrastructure, making it difficult to set up large-scale BSF systems that can effectively process organic waste from entire communities. As previously noted, BSF larvae require adequate space and resources to function optimally, and overcrowding of larvae can reduce their efficiency. Moreover, ensuring a consistent supply of organic waste is a significant logistical challenge, especially in densely populated urban settings where waste generation patterns may vary.

Despite these challenges, the scalability of BSF larvae-based systems can be enhanced through community-based approaches. Establishing localized breeding sites and waste processing units can help maintain a steady supply of larvae and optimize waste management. Community engagement ensures that households and businesses contribute organic waste to the system, creating a more sustainable and self-sufficient model. This approach could address some of the logistical hurdles associated with large-scale BSF larvae implementation, allowing for decentralized composting operations that are more manageable and adaptable to local contexts.

Environmental and Economic Advantages of BSF Larvae-Based Systems

The environmental benefits of BSF larvae-based waste management systems are significant. By converting organic waste into valuable products such as compost and protein-rich larvae biomass, BSF larvae help reduce the amount of waste sent to landfills, thus decreasing methane emissions and reducing the carbon footprint. Additionally, the nutrient-rich compost produced by BSF larvae can enhance soil fertility, promote sustainable urban farming practices, and improve local food security.

Economically, BSF larvae systems offer several advantages. The cost of producing BSF larvae is relatively low compared to traditional animal feed sources, as they require minimal land and water resources. The larvae's high feed conversion efficiency and rapid growth rate make them a cost-effective alternative to conventional feed ingredients, such as fish and soybean meal, subject to price volatility and environmental concerns. Moreover, by reducing reliance on traditional feed sources, BSF larvae can contribute to the sustainability of animal agriculture while offering a viable alternative for protein production.

The findings of this study on Black Soldier Fly (BSF) larvae in organic waste decomposition and compost production reveal significant advantages over traditional waste management and composting methods. Compared to aerobic composting, BSF larvae systems offer several key efficiency benefits by producing high-quality compost and addressing environmental concerns related to waste management. However, while the potential of BSF larvae systems in urban environments is evident, barriers to their widespread adoption exist, particularly regarding public perception, logistical integration, and regulatory challenges. This discussion critically examines the implications of these findings, contextualizing them within the broader literature and offering insights into the future potential of BSF larvae in sustainable urban waste management and farming systems.

As demonstrated in this study, one of the primary benefits of BSF larvae systems is their ability to accelerate organic waste decomposition significantly. The larvae's rapid processing capabilities, which result in over 80% reduction in waste volume within a matter of days, far surpass traditional aerobic composting methods that typically require weeks to months to achieve similar results. This rapid decomposition is due to BSF larvae's high feed conversion rate, which enables them to process large amounts of organic material efficiently, converting it into valuable compost and biomass. The ability to reduce waste quickly is crucial in urban environments, where waste generation is high, and space for waste disposal is limited. By converting organic waste into compost quickly, BSF larvae systems can reduce the amount of waste sent to landfills, thus alleviating the burden on municipal waste management systems.

In addition to their efficiency in waste decomposition, BSF larvae systems offer the added benefit of producing nutrient-rich compost and high-protein biomass, which can be used as animal feed. Traditional composting methods primarily produce organic matter but do not generate protein-rich biomass, which has significant economic value. BSF larvae, however, can be harvested as a byproduct, providing an alternative source of protein for animal feed, particularly for livestock and aquaculture. This dual-use of BSF larvae for waste reduction and protein production adds economic value to the process, making it a more sustainable and resource-efficient solution than conventional composting methods.

Despite these advantages, the widespread adoption of BSF larvae systems in urban waste management faces several challenges. Public perception remains one of the key barriers to the acceptance of insects as waste processors. In many cultures, insects are not traditionally associated with food or waste management, and there may be reluctance to embrace them as a viable solution, as Oemar et al. (2023) note. Public education campaigns are essential to dispel misconceptions and raise awareness about the benefits of BSF larvae. These campaigns can help people understand that BSF larvae are safe, efficient, and environmentally friendly waste processors. Additionally, pilot projects demonstrating the operational success of BSF systems can provide valuable data to ease regulatory concerns and build trust within the community.

Logistical challenges also present significant hurdles in integrating BSF larvae systems with existing waste management infrastructure. Urban areas often face issues related to space limitations, waste segregation, and the lack of facilities to support BSF larvae systems at a large scale. A key consideration is the need for specialized infrastructure to manage the larvae and the organic waste they process. Furthermore, integrating BSF larvae systems into municipal waste management programs requires cooperation between urban planners, environmental agencies, and local communities. Partnerships and collaborative efforts are essential for developing frameworks to support the widespread implementation of BSF larvae systems. Effective coordination can help streamline waste management processes, ensuring organic waste is efficiently collected, processed, and converted into valuable products.

Another significant consideration is the potential for integrating BSF larvae-based composting systems with urban farming models. Urban farming is vital in enhancing food security, reducing the carbon footprint of food production, and promoting sustainable agriculture. By converting local organic waste into nutrient-rich compost, BSF larvae systems can provide a sustainable source of fertilizer for urban farms, improving soil health and increasing crop yields. Using BSF larvae-derived compost in urban farming also reduces the need for synthetic fertilizers, which are often expensive and environmentally damaging. This symbiotic relationship between BSF larvae systems and urban agriculture can enhance the resilience and sustainability of urban food systems.

Moreover, community-based composting initiatives incorporating BSF larvae systems can foster a culture of sustainability and collaboration within urban agriculture. By engaging residents in waste management activities, these initiatives can create a sense of ownership and responsibility, empowering individuals to participate in waste reduction and sustainable farming practices. Highlight the importance of community involvement in the success of urban farming projects, noting that collective efforts can lead to more sustainable and equitable urban food systems.

The integration of BSF larvae systems into urban farming not only benefits food security but also contributes to improving public health. Organic waste that is not managed correctly can lead to the proliferation of disease vectors such as flies and rodents, which pose significant health risks in urban environments. With their rapid decomposition capabilities, BSF larvae help reduce the likelihood of vector proliferation by rapidly breaking down organic waste and minimizing decay. Furthermore, the composting process facilitated by BSF larvae generates high temperatures, which are detrimental to pathogens, resulting in safer compost use in agriculture. This thermophilic process makes BSF larvae systems safer and more hygienic than traditional composting methods, which can sometimes harbor pathogens due to slower decomposition processes.

The environmental implications of using BSF larvae for waste management are also significant. The rapid decomposition facilitated by BSF larvae helps reduce the amount of organic waste in landfills, decreasing methane emissions. Methane, a potent greenhouse gas, is a significant concern in landfills, where organic waste decomposes anaerobically. By accelerating the decomposition process and converting waste into valuable compost, BSF larvae systems can mitigate the environmental impacts of waste management in urban areas. Moreover, using BSF larvae in circular economy applications—where waste is transformed into valuable resources such as animal feed and compost—supports more sustainable and resource-efficient systems in urban settings.

However, scaling BSF larvae-based composting systems in urban areas presents several challenges. One major issue is the availability of space to establish the necessary infrastructure. Metropolitan areas are often densely populated, and space for waste processing and BSF larvae rearing is limited. Overcrowding of larvae can lead to diminished bioconversion efficiency, and managing waste at a suitable scale presents logistical hurdles. Moreover, variations in the composition of organic waste—ranging from food scraps to garden waste—can impact the efficiency of BSF larvae in processing different types of garbage. Horgan et al. (2023) suggest that optimizing larval rearing conditions and waste inputs can improve bioconversion efficiency, but the scalability of these systems remains a significant challenge in urban settings.

In conclusion, while using BSF larvae in urban waste management systems offers numerous environmental, economic, and social benefits, successfully adopting these systems requires overcoming several barriers. Public perception, logistical challenges, and regulatory concerns must be addressed to ensure the widespread implementation of BSF larvae systems. Collaboration between urban planners, environmental agencies, and local communities will be crucial in establishing the necessary frameworks for scaling BSF larvae systems. By overcoming these challenges, BSF larvae-based composting can contribute to sustainable urban waste management, enhance food security through urban farming, and promote healthier urban environments. Integrating BSF larvae systems into urban agriculture represents a promising avenue for creating more sustainable, resilient, and resource-efficient cities.

Conclusion

This study highlights that Black Soldier Fly (BSF) larvae are an efficient solution for organic waste management, achieving up to 86% waste reduction in a few days, producing nutrient-rich compost beneficial for urban farming, and offering protein-rich biomass for animal feed. The findings underscore the potential of BSF larvae to reduce landfill waste, lower methane emissions, and enhance food security through sustainable urban farming practices. However, challenges related to scalability, public perception, and logistical integration with existing systems remain. Future research should focus on optimizing BSF larvae systems for large-scale urban adoption and exploring the long-term benefits of BSF-derived compost on soil health and crop productivity. This research contributes to the growing field of sustainable waste management and urban agriculture, offering a promising pathway toward more resilient and resource-efficient cities.

References

[1] M.Rao, R.Chhabria, A.Gunasekaran, Andp.Mandal, "Improving Competitiveness Through Performance Evaluation Using The APC Model: A Case In Micro-Irrigation," *Int. J. Prod. Econ.*, Vol. 195, Pp. 1–11, 2018, Doi: 10.1016/J.Ijpe.2017.09.017.

[2] Y.Zhao, "A Comparative Analysis Of CSR In Developed And Developing Countries-A Qualitative Case Study Of Walmart And JD.Com," *BCP Bus. Manag.*, Vol. 23, Pp. 189–197, 2022, Doi: 10.54691/Bcpbm.V23i.1350.

[3] Suhendra And R. R. S.Nurdianti, "Indonesian Journal Of Primary Education Penggunaan Metode Servqual Dalam Pengukuran Kualitas Layanan Pendidikan," *Indones. J. Prim. Educ.*, Vol. 2, No. 2, Pp. 71–75, 2018.

[4] H.Sallehudin, R.Che Razak, M.Ismail, A. F.Md Fadzil, And R.Baker, "Cloud Computing Implementation In The Public Sector: Factors And Impact," *Asia-Pacific J. Inf. Technol. Multimed.*, Vol. 07, No. 02(02), Pp. 27–42, 2018, Doi: 10.17576/Apjitm-2018-0702(02)-03.

[5] R. V. B. Desouza And L. C. R.Carpinetti, "A FMEA-Based Approach To Prioritize Waste Reduction In Lean Implementation," *Int. J. Qual. Reliable. Manag.*, Vol. 31, No. 4, Pp. 346–366, 2014, Doi: 10.1108/IJQRM-05-2012-0058.

[6] E.Taniguchi, R. G.Thompson, And A. G.Qureshi, "Modelling City Logistics Using Recent Innovative Technologies," *Transp. Res. Procedia*, Vol. 46, No. 2019, Pp. 3–12, 2020, Doi: 10.1016/J.Trpro.2020.03.157.

[7] H.Paloheimo, M.Lettenmeier, Andh.Waris, "Transport Reduction By Crowdsourced Deliveries – A Library Case In Finland," *J. Clean. Prod.*, Vol. 132, Pp. 240–251, 2016, Doi: 10.1016/J.Jclepro.2015.04.103.

[8] D.Siwiec, A.Pacana, Anda.Gazda, "A New QFD-CE Method For Considering The Concept Of Sustainable Development And Circular Economy," *Energies*, Vol. 16, No. 5, 2023, Doi: 10.3390/En16052474.

[9] M. H.Dachan, "The Reverse Supply Chains Of The Fast-Moving Consumer Goods: Ththe Reverse Supply Chains Of The Fast-Moving Consumer Goods: The Impacts Of Product Returns On Reverse Supply Chains In Swedene Impacts Of Product Returns On Reverse Supply Chains In Sweden," Jonkoping University, 2023.

[10] A. Agarwal And R.Ojha, "Prioritising The Determinants Of Industry-4.0 For Implementation In MSME In The Post-Pandemic Period – A Quality Function Deployment Analysis," *TQM J.*, Vol. 35, No. 8, 2023, Doi: 10.1108/TQM-06-2022-0204.

[11] E. Pourrahmani And M.Jaller, "Crowdshipping In Last Mile Deliveries: Operational Challenges And Research Opportunities," *Socioecon. Plan. Sci.*, Vol. 78, No. August 2020, P. 101063, 2021, Doi: 10.1016/J.Seps.2021.101063.

[12] A. S. Soegoto And H.Karamoy, "Competitive Strategy Analysis To Increase Consumer Purchasing Decisions On Minimarket Business," *Etikonomi*, Vol. 19, No. 1, Pp. 119–130, 2020, Doi: 10.15408/Etk.V19i1.14337.

[13] R.Golnaz, M.Zainalabidin, S.Mad Nasir, Andf. C.Eddie Chiew, "Non-Muslims' Awareness Of Halal Principles And Related Food Products In Malaysia," *Int. Food Res. J.*, Vol. 17, No. 3, Pp. 667–674, 2010.

[14] E. J. Martins And F. P.Belfo, "Major Concerns About Enterprise Resource Planning (ERP) Systems: A Systematic Review Of A Decade Of Research (2011-2021)," *Procedia Comput. Sci.*, Vol. 219, Pp. 378–387, 2023, Doi: 10.1016/J.Procs.2023.01.303.

[15] M.Isoraite, "Sustainable Digital Marketing And The Digital Supply Chain Management Theoretical Aspects BT - TRANSBALTICA XIV: Transportation Science And Technology," O.Prentkovskis, I.Yatskiv (Jackiva), P.Skačkauskas, M.Karpenko, And M.Stosiak, Eds., Cham: Springer Nature Switzerland, 2024, Pp. 223–228.

[16] K.Sallam, A. W.Mohamed, And M.Mohamed, "Internet Of Things (Iot) In Supply Chain Management: Challenges, Opportunities, And Best Practices," *Sustain. Mach. Intell. J.*, Vol. 2, Pp. 1–32, 2023, Doi: 10.61185/Smij.2023.22103.

[17] H. Ardodi And Y. M.Pasaribu, "Tantangan Dan Kompetensi Kunci Desainer Produk Industri Dalam Membangun Masa Depan Sepeda Motor Listrik Nasional Di Era Teknologi 4.0," *J. Desain Indones.*, Vol. 6, No. 1, Pp. 15–38, 2024.

[18] S. S. S. S.Liu, "Preventive Maintenance Model For National School Buildings In Indonesia Using A Constraint Programming Approach," *Sustain.*, Vol. 13, No. 4, Pp. 1–25, 2021, Doi: 10.3390/Su13041874.

[19] M. Zaenuri And H.Catur, "Analisa Kualitas Layanan Terhadap Kepuasan Pelanggan Dengan Metode QFD Dan CSI Pada Konsumen Gojek Di Surabaya (Studi Kasus: GO-JEK Di Surabaya)," *J. SENOPATI Sustain. Ergon. Optim. Appl. Ind.. Eng.*, Vol. 3, No. 2, Pp. 74–83, 2022, Doi: 10.31284/J.Senopati.2022.V3i2.2504.

[20] M.Zheng, "Comprehensive Life Cycle Environmental Assessment Of Preventive Maintenance Techniques For Asphalt Pavement," *Sustain.*, Vol. 13, No. 9, 2021, Doi: 10.3390/Su13094887.

[21] A. Fonseka And D.Alahakoon, "Exploratory Data Analysis With Multi-Layer Growing Self-Organizing Maps," In *Proceedings Of The 2010 5th International Conference On*

Information And Automation For Sustainability, Iciafs 2010, 2010, Pp. 132–137. Doi: 10.1109/ICIAFS.2010.5715648.

[22] A. H.Ngah, R.Thurasamy, N. A.Aziz, H.Ali, And M. I.Khan, "Modelling The Adoption Of Halal Warehousing Services Among Halal Pharmaceutical And Cosmetic Manufacturers," *J. Sustain. Sci. Manag.*, Vol. 14, No. 6, Pp. 103–116, 2019.

[23] E.Župerkienė, L.Šimanskienė, D.Labanauskaitė, J.Melnikova, Andv.Davidavičienė, "The COVID-19 Pandemic And Resilience Of SME's In Lithuania," *Entrep. Sustain. Issues*, Vol. 8, No. 3, Pp. 53–65, 2021, Doi: 10.9770/Jesi. 2021.8.3(4).

[24] F. F. Li, R. Y. M. Chau, K. W., & Zeng, "Ranking Of Risks For Existing And New Building Works," *Sustainability*, Vol. 11, No. 10, 2019.

[25] N.Ahmad, D.Alahakoon, And R.Chau, "Classification Of Protein Sequences Using The Growing Self-Organizing Map," In *Proceedings Of The 2008 4th International Conference On Information And Automation For Sustainability, ICIAFS 2008*, 2008, Pp. 167–172. Doi: 10.1109/ICIAFS.2008.4783969.

[26] A.Sa'ad, "Improved Preventive Maintenance Scheduling For A Photovoltaic Plant Under Environmental Constraints," *Sustain.*, Vol. 13, No. 18, 2021, Doi: 10.3390/Su131810472.

[27] H.-L.Chen, Y.Hu, M.-Y.Lee, Andg.Yen, "Importance Of Employee Care In Corporate Social Responsibility: An AHP-Based Study From The Perspective Of Corporate Commitment," *Sustainability*, 2020, Doi: 10.3390/Su12155885.

[28] N. F.Shayan, "Sustainable Development Goals (Sdgs) As A Framework For Corporate Social Responsibility (CSR)," *Sustain. Switz.*, Vol. 14, No. 3, 2022, Doi: 10.3390/Su14031222.