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Ecosystem Model of Edu-Tourism for Organic Waste Conversion in Islamic Boarding Schools through Maggot Cultivation

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Abstract

The purpose of this research is to determine the relationship between the Edu-Tourism Ecosystem Model of Organic Waste Conversion in Islamic Boarding Schools and maggot cultivation. This research began by finding a picture of waste processing in Islamic boarding schools, which was further developed by analyzing the feasibility of business and waste processing management. The results of this study offer the concept of eduwisata maggot-based organic waste processing in Islamic boarding schools.This research is qualitative, using a study-case approach, with the object of research being the Islamic Boarding School in Bangkalan, which has at least 1,000 students. There are five Islamic boarding schools that meet the criteria: Al Aziziyah, Asshomadiyah, Nurul Kholil, Shaikhona Kholil, and Nurul Amanah. According to the study's findings, the results of the business feasibility analysis produced positive value both economically, technically, and, to the greatest extent possible, in marketing. The feasibility analysis of the business needs to be supported by good processing management through planning, organizing, actuating, and controlling. Furthermore, the concept of maggot-based organic waste treatment (eduwisata) is integrated by combining tutorial learning activities with on-site exploration activities.

Keywords: *Maggot, Edu-Tourism, Pesantren, conversion, and organic waste*

Introduction

Indonesia is one of the most populous countries in the world, a condition that significantly contributes to the continuous increase in waste generation. This rise is not proportionate to the existing waste management capacity, resulting in serious environmental issues such as pollution and methane gas emissions. The methane gas explosion at the Leuwigajah landfill site in 2005 serves as a critical example of inadequate waste management practices, which led to severe environmental damage and loss of life. Data from the Ministry of Environment and Forestry indicate that national waste generation reached 67.8 million tons in 2020, with organic waste accounting for 57%, followed by plastic (15%), paper (11%), and other types (17%) (Kementerian Lingkungan Hidup dan Kehutanan, 2020). This condition highlights that organic waste management remains a major challenge in Indonesia.

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Waste management practices in Indonesia largely still rely on a linear model of collect–transport–dispose, which is considered inefficient and unsustainable. In contrast, many developed countries have transitioned to circular economy approaches that emphasize waste valorization through reduce, reuse, and recycle (3R) principles (Lalander et al., 2019). Similar challenges are also evident at the regional level, where increasing waste generation continues to put pressure on local waste management systems. The dominance of organic waste within the total waste composition presents a significant opportunity for more innovative and environmentally sustainable management approaches.

One promising alternative for organic waste treatment is the cultivation of Black Soldier Fly (BSF) larvae or maggots (*Hermetia illucens*). BSF larvae possess a high capacity to decompose organic waste efficiently and rapidly. Studies have shown that BSF larvae can significantly reduce organic waste volume while minimizing environmental impacts such as odor and greenhouse gas emissions (Diener et al., 2011; Lalander et al., 2019). This bioconversion process is environmentally friendly and relatively safe, as BSF is not classified as a disease vector. Moreover, it produces valuable by-products such as animal feed and organic fertilizer (frass) (Surendra et al., 2016). The high nutritional content of maggots, including protein, lipids, and amino acids, further supports their potential as an alternative feed source (Barragán-Fonseca et al., 2017).

Previous studies have examined the utilization of maggots in organic waste management, including their use for compost production and livestock feed (Mulyani et al., 2021), as well as their potential in improving waste management systems through practical applications (Auliani et al., 2021). However, these studies remain largely partial and have not comprehensively explored an integrated ecosystem model that incorporates social, economic, and educational dimensions. This gap underscores the need for a more holistic approach to sustainable, community-based organic waste management. In addition, the growing global concern over climate change and environmental degradation further strengthens the urgency to adopt innovative waste management solutions. Organic waste, when improperly managed, contributes significantly to methane emissions, a greenhouse gas with a global warming potential far greater than carbon dioxide (IPCC, 2021). Therefore, transforming organic waste into valuable resources through technologies such as BSF bioconversion aligns with global sustainability agendas, including the Sustainable Development Goals (SDGs), particularly those related to responsible consumption and production, climate action, and sustainable communities. Moreover, community-based institutions such as pesantren play a strategic role in promoting environmental awareness and behavioral change due to their strong social influence and educational function. By integrating waste management practices with educational activities, pesantren can act as agents of change in fostering environmentally responsible communities. This reinforces the importance of developing a comprehensive model that not only addresses technical and economic aspects but also incorporates educational and social transformation as key components of sustainable waste management systems.

The urgency of addressing organic waste management in Indonesia is further intensified by the accelerating rate of urbanization, population growth, and changing consumption patterns. Without immediate and systemic intervention, the gap between waste generation

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and management capacity will continue to widen, leading to more severe environmental degradation and public health risks. The recurrence of landfill overcapacity, illegal dumping, and unmanaged organic waste accumulation highlights the limitations of current systems and the need for transformative solutions. Furthermore, the economic loss associated with untreated organic waste, which could otherwise be converted into valuable resources, represents a missed opportunity for sustainable development. In this context, adopting innovative approaches such as BSF-based bioconversion is not merely an option but a necessity. Integrating this approach within community-based institutions like pesantren adds an additional layer of urgency, as these institutions have the potential to function as replication models for broader societal adoption. Therefore, developing an integrated system that combines waste management, education, and economic empowerment is crucial to ensure long-term environmental sustainability and resilience.

Based on this context, this study aims to develop an eco-edutourism ecosystem model for organic waste conversion through maggot cultivation. This approach is expected to integrate waste management, environmental education, and economic value creation in a sustainable manner. Islamic boarding schools (pesantren) are selected as the research setting due to their characteristics as dense social communities with significant daily organic waste generation. Given this potential, pesantren can serve as strategic models for maggot-based waste management while simultaneously functioning as centers for environmental education. This study focuses on analyzing existing waste management practices, developing a maggot-based management model, and formulating an eco-edutourism concept as an innovative solution for sustainable organic waste management.

Literature Review

Organic Waste Management and Circular Economy

The increasing volume of organic waste has emerged as a major environmental challenge, particularly in developing countries such as Indonesia. Organic waste constitutes more than half of total municipal solid waste, creating significant pressure on existing waste management systems while simultaneously offering opportunities for resource recovery (Kementerian Lingkungan Hidup dan Kehutanan, 2020). However, current waste management practices in many developing regions still rely on conventional linear approaches, collect, transport, and dispose, which are widely recognized as inefficient and unsustainable in the long term (Lalander et al., 2019). These systems often result in landfill overcapacity, environmental degradation, and the emission of greenhouse gases such as methane.

In response to these challenges, the concept of a circular economy has gained increasing attention as a sustainable alternative. The circular economy emphasizes the efficient use of resources through strategies such as reduce, reuse, and recycle (3R), aiming to minimize waste generation and maximize resource utilization (Geissdoerfer et al., 2017). This approach shifts the perception of waste from an environmental burden to a valuable resource that can be reintegrated into production systems. In the context of organic waste, circular economy practices include composting, anaerobic digestion, and biological conversion technologies.

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Despite its advantages, the implementation of circular economy principles in developing countries remains limited due to institutional, technological, and behavioral constraints. Factors such as lack of infrastructure, limited public awareness, and insufficient policy support hinder the transition from linear to circular systems. Therefore, innovative and adaptable solutions are needed to bridge this gap. One such solution is the integration of community-based waste management systems that utilize locally available resources and simple technologies. This approach not only supports environmental sustainability but also creates economic opportunities at the local level, making it particularly relevant for institutions such as Islamic boarding schools (pesantren).

Black Soldier Fly (BSF) Bioconversion Technology

The utilization of Black Soldier Fly (BSF) larvae (*Hermetia illucens*) has emerged as one of the most promising innovations in organic waste management. BSF larvae are highly efficient decomposers capable of rapidly converting organic waste into biomass through a process known as bioconversion. Research indicates that BSF larvae can reduce organic waste volume significantly within a short period, while also minimizing environmental impacts such as odor and greenhouse gas emissions (Diener et al., 2011; Lalander et al., 2019). Compared to conventional composting methods, BSF technology offers faster processing times and higher efficiency, making it suitable for decentralized and small-scale applications.

The biological characteristics of BSF larvae contribute to their effectiveness in waste management. They can consume organic waste at a rate of two to five times their body weight per day, enabling rapid waste reduction. Moreover, BSF larvae are not considered disease vectors, making them relatively safe for use in waste processing systems. This feature is particularly important for applications in densely populated environments such as pesantren.

In addition to waste reduction, BSF bioconversion produces valuable by-products. The larvae are rich in protein, lipids, and essential amino acids, making them a viable alternative to conventional animal feed ingredients such as fishmeal and soybean meal (Barragán-Fonseca et al., 2017). Meanwhile, the residual waste product, known as frass, can be used as organic fertilizer to improve soil quality and support sustainable agriculture (Surendra et al., 2016). These outputs highlight the dual environmental and economic benefits of BSF technology.

Given its efficiency, low operational requirements, and economic potential, BSF bioconversion is increasingly recognized as a practical solution for organic waste management, particularly in resource-limited settings.

Previous Studies on Maggot-Based Waste Management

A growing body of literature has examined the application of maggot-based waste management, particularly through the use of BSF larvae, in various contexts. Previous studies have demonstrated that integrating organic waste processing with maggot cultivation can provide both environmental and economic benefits. For instance, Mulyani

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et al. (2021) found that community-based maggot cultivation systems can reduce organic waste while simultaneously generating income through the production of animal feed and organic fertilizer. Similarly, Auliani et al. (2021) highlighted the potential of BSF bioconversion as a practical and scalable solution for improving local waste management practices.

Other studies have focused on the efficiency and adaptability of BSF technology. Lalander et al. (2019) emphasized its effectiveness in reducing waste volume and environmental impact, while Gold et al. (2018) discussed its potential to support small-scale enterprises and contribute to sustainable livelihoods. In addition, research by Diener et al. (2011) demonstrated that BSF larvae can process a wide range of organic waste types, making the technology highly versatile.

Despite these promising findings, most existing studies tend to focus primarily on technical feasibility and economic outcomes. There is limited research that explores the integration of social, educational, and ecological dimensions within maggot-based waste management systems. In particular, the role of community institutions, such as pesantren, in facilitating sustainable waste management practices has not been extensively examined.

This gap indicates the need for a more comprehensive approach that goes beyond technical implementation and considers the broader socio-economic and educational context. Integrating these dimensions is essential for ensuring the long-term sustainability and scalability of maggot-based waste management systems.

Eco-Edutourism Approach in Waste Management

Eco-edutourism has emerged as an innovative approach that integrates environmental education with tourism activities to promote sustainability. This concept combines elements of ecological conservation, experiential learning, and community-based economic development (Fennell, 2020). In the context of waste management, eco-edutourism provides a platform for educating the public about environmental issues while simultaneously creating economic opportunities.

The eco-edutourism model emphasizes interactive and experiential learning. Visitors are not only provided with theoretical knowledge but also engage directly in practical activities, such as observing or participating in waste processing systems. This approach enhances understanding and fosters behavioral change toward more sustainable practices. In addition, eco-edutourism can increase public awareness of innovative waste management technologies, such as BSF bioconversion.

Supporting elements of eco-edutourism include trained guides, educational facilities, structured visitor pathways, and effective communication strategies. These components are essential for delivering meaningful learning experiences and ensuring visitor satisfaction. Furthermore, the integration of tourism and education can generate additional income streams for local communities, contributing to economic resilience.

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Despite its potential, the application of eco-edutourism in organic waste management remains limited, particularly in institutional settings such as Islamic boarding schools (pesantren). Given their characteristics as dense social environments with structured activities, pesantren offer strong potential as sites for implementing eco-edutourism-based waste management models. By integrating maggot-based bioconversion with educational tourism, pesantren can serve as centers for environmental learning while also addressing waste management challenges.

This integrated approach represents a holistic solution that combines environmental sustainability, education, and economic development, making it highly relevant for future research and practical implementation.

Research Methods

This study employs a qualitative research design, also referred to as a naturalistic inquiry approach (Moleong, 2019). According to Creswell (2015), qualitative research is grounded in a set of assumptions and interpretive or theoretical frameworks that shape the investigation of research problems, particularly in understanding the meanings individuals or groups assign to social phenomena. Similarly, Denzin et al. (2011) define qualitative research as an interpretive practice that seeks to understand and explain phenomena based on the meanings constructed by society. This perspective aligns with Moleong (2019), who emphasizes that qualitative research adopts a naturalistic approach to explore and gain in-depth understanding of phenomena within their specific contextual settings. The sampling technique employed in this study is purposive sampling. The researcher established five specific criteria to determine eligible research objects. These criteria are presented as follows:

The selection of research objects in this study was based on several predetermined criteria to ensure the relevance and adequacy of the data obtained. First, the research objects must be Islamic boarding schools (*pesantren*) with formal institutional legality and a minimum population of 1,000 students, ensuring that the institutions represent large and structured social communities. Second, the selected pesantren are required to have prior experience in managing organic waste through maggot cultivation using Black Soldier Fly (*Hermetia illucens*), indicating their practical involvement in sustainable waste management practices. Third, the institutions must demonstrate transparency and openness in providing information to support both the research process and broader public dissemination. Finally, data were collected from key informants who are directly involved in or related to waste management activities, including boarding school leaders (caretakers), sanitation or environmental management staff, as well as representatives from the local Environmental Agency and the Livestock and Fisheries Agency. Based on these criteria, five Islamic boarding schools were selected as research sites: Pondok Pesantren Al Aziziyah, Pondok Pesantren Syaikhona Kholil, Pondok Pesantren Nurul Kholil, Pondok Pesantren Asshomadiyah, and Pondok Pesantren Nurul Amanah.

Results and Discussion

Business Feasibility Analysis of Maggot-Based Organic Waste Management

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The feasibility analysis of maggot-based organic waste management in Islamic boarding schools (*pesantren*) was examined through four key dimensions: technical, human resources, market and marketing, and financial feasibility. These aspects collectively determine the viability and sustainability of implementing Black Soldier Fly (BSF) larvae (*Hermetia illucens*) as a bioconversion agent within a community-based institutional setting.

From a technical perspective, the cultivation process begins with waste mapping to estimate the volume and composition of organic waste, which subsequently determines the capacity and design of maggot rearing facilities. This step is crucial in ensuring operational efficiency and resource optimization (Salman et al., 2020). The production cycle consists of several stages, including egg hatching, early larval feeding using organic waste substrates, transfer to bioponds for growth, harvesting at the larval stage (approximately 10–15 days), and further development into prepupa and pupa for breeding purposes. The application of relatively simple and low-cost technologies, such as waste shredders and modular biopond systems, demonstrates that this method is both technically feasible and adaptable to the pesantren environment, which typically operates with limited infrastructure (Mulyani et al., 2021).

In terms of human resources, maggot cultivation is considered labor-efficient and scalable. A small-scale production system, with an output capacity of approximately 280 kg per cycle, can be effectively managed by a single worker, while larger-scale operations may require two or more personnel depending on production intensity. However, the success of the system is highly dependent on the technical competence of workers, particularly in waste segregation, feeding management, and lifecycle monitoring. Therefore, capacity-building initiatives such as training and skill development are essential to ensure consistent production quality and operational sustainability (Auliani et al., 2021).

From a market and marketing perspective, maggot cultivation offers substantial economic potential due to the diversity of products generated throughout the lifecycle. These include maggot eggs, fresh larvae, dried larvae, and organic fertilizer (frass), all of which have established demand in sectors such as livestock farming, aquaculture, and agriculture. The economic value of these products varies significantly, with processed outputs such as dried maggots providing higher profit margins due to their longer shelf life and broader market reach (Widodo et al., 2021). Marketing strategies are predominantly direct, involving distribution to local farmers and agricultural stakeholders, which reduces intermediary costs and strengthens local economic linkages. Additionally, the strategic placement of production facilities near waste sources enhances operational efficiency by minimizing transportation costs and ensuring a continuous supply of raw materials.

Financially, the analysis indicates strong business feasibility. The initial investment required for infrastructure development, such as bioponds and rearing cages, is relatively low compared to other waste management technologies. Operational costs, including labor and feedstock (organic waste), remain manageable due to the utilization of locally available resources. Profit projections reveal a stable annual net income, supported by consistent demand for maggot-based products. The payback period is notably short, estimated at approximately 0.5 years (five months), indicating rapid return on investment. Furthermore, the Net Present Value (NPV) is positive, and the Profitability Index (PI) exceeds 1,

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confirming that the business is financially viable and economically attractive (Sasongko et al., 2021).

Management of Maggot-Based Organic Waste Processing

The management system of maggot-based organic waste processing in Islamic boarding schools (*pesantren*) can be systematically understood through the classical management framework of planning, organizing, actuating, and controlling (POAC). This approach provides a structured foundation for ensuring that waste management practices are not only operationally effective but also sustainable and scalable within community-based institutions.

The planning phase constitutes the initial and most strategic stage, involving the formulation of institutional vision and mission aligned with environmental sustainability goals. In this phase, comprehensive mapping of organic waste generation is conducted to determine both the volume and characteristics of waste produced on a daily basis. This mapping becomes the basis for designing an integrated waste management system that categorizes waste into organic, inorganic, and hazardous fractions. Organic waste is prioritized for processing through maggot-based bioconversion, while inorganic waste is directed toward recycling streams and hazardous waste is handled separately following environmental safety standards (Diener et al., 2011). Supporting technical processes such as waste shredding and fermentation are incorporated to enhance the nutritional quality and digestibility of feed substrates for Black Soldier Fly (BSF) larvae, thereby increasing conversion efficiency (Lalander et al., 2019).

The organizing phase focuses on establishing a clear and functional institutional structure to support operational activities. Effective waste management requires the allocation of roles and responsibilities across multiple divisions, including leadership, financial administration, human resource development, waste management operations, production, and marketing. Each unit is assigned specific tasks to ensure coordination and efficiency in workflow. For instance, the waste management division is responsible for waste segregation and collection, while the production unit oversees maggot cultivation processes. Meanwhile, the marketing division manages product distribution and stakeholder engagement. Such organizational structuring is critical in community-based systems, as it enhances accountability, improves communication, and ensures the continuity of operations (Guerrero et al., 2013).

The actuating phase represents the implementation stage, where planned activities are translated into real operational processes. In this context, maggot cultivation is carried out using simple, low-cost, and locally adaptable technologies, such as bioponds, rearing cages, and waste processing equipment. The production cycle is relatively short, typically ranging from 10 to 15 days for larval harvesting, which allows for rapid turnover and continuous production. The availability of a consistent organic waste supply within pesantren environments further supports the sustainability of this system. Moreover, the simplicity of the cultivation process enables easy adoption by students and staff, making it not only a waste management solution but also a practical educational tool (Barragan-Fonseca et al., 2017).

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The controlling phase involves systematic monitoring and evaluation to ensure that all operational activities adhere to established standard operating procedures (SOPs). Regular supervision is essential to maintain productivity, identify potential inefficiencies, and prevent deviations that may affect output quality or environmental safety. This phase also includes performance assessment, feedback mechanisms, and continuous improvement strategies to enhance system effectiveness over time. Effective control mechanisms contribute significantly to the long-term sustainability of maggot-based waste management systems, particularly in institutional settings where consistency and discipline are key factors (Parra Paz et al., 2015). The application of the POAC management framework demonstrates that maggot-based organic waste processing in pesantren is not only technically feasible but also managerially robust. By integrating structured planning, clear organizational roles, effective implementation, and continuous monitoring, this model offers a comprehensive approach to sustainable waste management while simultaneously supporting educational and economic objectives.

Eco-Edutourism Model for Organic Waste Management

The study further identifies a strategic opportunity to integrate maggot-based organic waste management into an eco-edutourism framework. This model combines environmental education, community participation, and experiential tourism into a single, holistic system. Eco-edutourism is increasingly recognized as an effective approach to promote sustainability awareness while simultaneously generating economic value through educational tourism activities (Weaver, 2006). In the context of pesantren, this model is particularly relevant, as these institutions function not only as educational centers but also as community hubs with strong social and cultural engagement.

The proposed eco-edutourism model is structured into two main stages: tutorial-based learning and site-based exploration. The tutorial phase serves as the foundational learning stage, where visitors are introduced to essential concepts of waste management, environmental sustainability, and maggot-based bioconversion. Educational delivery methods include interactive media such as visual displays, infographics, videos, and guided explanations. This approach aligns with experiential learning theory, which emphasizes the importance of combining conceptual understanding with practical engagement to enhance knowledge retention (Kolb, 1984). By presenting information in an accessible and engaging manner, visitors can develop a clear understanding of the environmental challenges associated with organic waste and the innovative solutions offered by Black Soldier Fly (BSF) technology.

The second stage, site-based exploration, provides visitors with direct, hands-on experience in observing and engaging with the waste management system. In this phase, visitors are guided through different operational areas, including waste segregation points, organic waste processing units, maggot cultivation facilities, and product output sections such as dried larvae and organic fertilizer (frass). This immersive experience allows visitors to witness the full cycle of waste bioconversion, thereby reinforcing the knowledge gained during the tutorial phase. Direct engagement has been shown to significantly enhance environmental awareness and behavioral change, as individuals are more likely to adopt

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sustainable practices when they observe real-world applications (Ballantyne & Packer, 2011).

To ensure the effectiveness of this model, several supporting elements are required. First, the presence of trained guides or interpreters is essential to facilitate communication and enhance visitor understanding. These guides must possess not only technical knowledge but also strong communication skills to engage diverse visitor groups. Second, the availability of educational facilities, such as information boards, demonstration areas, and multimedia tools, plays a critical role in delivering structured learning experiences. Third, the design of visitor circulation pathways is important to ensure a smooth and organized flow of movement throughout the site, minimizing disruption to operational activities while maximizing visitor exposure to key learning points. Lastly, interpretive communication strategies, such as storytelling, contextual explanations, and interactive discussions, are necessary to create meaningful and memorable experiences for visitors (Ham, 2013).

The integration of these components results in a comprehensive eco-edutourism model that not only enhances visitor engagement but also strengthens environmental literacy. Furthermore, this model creates additional economic opportunities for pesantren through tourism-based income, product sales, and educational programs. It also reinforces the role of pesantren as agents of sustainable development by demonstrating practical solutions to local environmental challenges. In the long term, the eco-edutourism approach has the potential to foster a culture of sustainability, encourage community participation, and contribute to the development of circular economy practices at the grassroots level (UNWTO, 2018).

Discussion

The findings of this study demonstrate that maggot-based organic waste management in Islamic boarding schools (*pesantren*) is not only technically feasible but also economically viable and socially adaptable. The relatively simple technology involved in Black Soldier Fly (BSF) (*Hermetia illucens*) cultivation, combined with low operational requirements, makes this model particularly suitable for community-based institutions with limited financial and infrastructural capacity. This aligns with previous studies indicating that BSF-based systems are highly adaptable to decentralized waste management contexts, especially in developing countries (Diener et al., 2011; Lalander et al., 2019).

From a sustainability perspective, the implementation of maggot-based waste processing strongly reflects the principles of a circular economy. Organic waste, which traditionally represents an environmental burden, is transformed into high-value products such as animal feed and organic fertilizer. This process not only reduces the volume of waste sent to landfills but also minimizes greenhouse gas emissions, particularly methane, which is commonly associated with unmanaged organic waste decomposition (Parra Paz et al., 2015). Furthermore, the short production cycle, typically ranging from 10 to 15 days for larval harvesting, combined with the high efficiency of BSF larvae in consuming organic waste (up to several times their body weight per day), enhances the practicality and scalability of this model as an alternative waste management solution (Barragan-Fonseca et al., 2017).

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Economically, the findings indicate that maggot cultivation offers a promising source of income diversification for pesantren. The ability to generate multiple marketable products across different stages of the maggot lifecycle, such as eggs, fresh larvae, dried larvae, and frass, provides flexibility in responding to market demand. This diversification reduces economic risk and enhances financial resilience, particularly in rural or semi-urban areas where alternative income sources may be limited (Surendra et al., 2020). Additionally, the relatively low initial investment and short payback period further strengthen the attractiveness of this business model, making it accessible for small-scale institutional adoption.

However, despite its technical and economic advantages, the success of maggot-based waste management systems is highly dependent on effective management practices and the capacity of human resources. The study highlights the importance of implementing structured organizational systems, including clear division of roles and responsibilities, to ensure operational efficiency. This finding is consistent with Guerrero et al. (2013), who emphasize that institutional and managerial factors are critical determinants of success in community-based waste management systems. Continuous training and capacity-building initiatives are also essential, particularly in enhancing technical skills related to waste segregation, larval cultivation, and product handling. Without adequate training, inconsistencies in operational practices may reduce productivity and compromise system sustainability.

Another important aspect highlighted in this study is the role of market accessibility and product diversification in ensuring economic sustainability. While the demand for maggot-based products, especially as alternative animal feed, continues to grow, access to stable and broader markets remains a key challenge. Effective marketing strategies, including the development of value-added products such as dried larvae and packaged organic fertilizer, can significantly enhance market competitiveness and profitability (van Huis, 2020). In this regard, establishing partnerships with local farmers, aquaculture businesses, and agricultural cooperatives can strengthen supply chains and improve market integration.

A distinctive contribution of this study lies in the integration of eco-edutourism into the maggot-based waste management model. This approach introduces an innovative dimension by linking environmental management with education and tourism activities. Through structured learning experiences and direct observation, visitors gain practical insights into sustainable waste processing, thereby increasing environmental awareness and promoting pro-environmental behavior (Ballantyne & Packer, 2011). Moreover, eco-edutourism enhances community engagement and strengthens the institutional visibility of pesantren as centers of sustainability innovation. Compared to previous studies that primarily focus on technical efficiency or economic benefits, this integrated model offers a more holistic framework by incorporating social, educational, and environmental dimensions.

Despite these promising outcomes, several challenges remain that may hinder the broader implementation and scalability of this model. Financial limitations continue to be a significant constraint, particularly in the initial stages of infrastructure development and operational setup. Although the investment required is relatively low, access to capital or external funding support is still necessary for scaling up operations. Additionally, issues

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related to labor discipline and consistency have been identified as potential barriers. Irregular participation and lack of commitment among workers or participants can disrupt production cycles and reduce overall efficiency.

Furthermore, public perception regarding maggot cultivation presents another challenge. In some communities, the use of larvae in waste processing is still associated with negative connotations, including concerns about hygiene, safety, and cultural acceptance. These perceptions may limit community participation and acceptance of the system. Therefore, targeted education and awareness programs are essential to address misconceptions and promote a better understanding of the environmental and economic benefits of BSF technology (Čičková et al., 2015).

In addition, policy support and institutional integration are crucial for ensuring long-term sustainability. The absence of clear regulatory frameworks or government incentives for organic waste bioconversion may limit the expansion of such initiatives. Strengthening collaboration between pesantren, local governments, and environmental agencies can facilitate access to resources, technical assistance, and policy support. Integrating maggot-based waste management into broader waste management strategies at the regional or national level would further enhance its impact and scalability. This study demonstrates that maggot-based organic waste management in pesantren represents a viable, sustainable, and innovative solution to address organic waste challenges. Its alignment with circular economy principles, combined with its economic potential and adaptability to local contexts, makes it a promising model for community-based waste management.

The integration of eco-edutourism further strengthens its value by promoting environmental education and community engagement. However, to fully realize its potential, it is essential to address existing challenges through improved management practices, capacity building, market development, community education, and stronger institutional and policy support.

Moreover, the long-term sustainability of this model is closely linked to its ability to foster behavioral change within the pesantren community. Waste segregation at the source remains a fundamental prerequisite for the efficiency of maggot-based systems, yet it requires consistent awareness and discipline among students and staff. Embedding environmental values into daily routines, supported by continuous education and institutional regulations, can significantly improve participation and system effectiveness. In this regard, pesantren possess a unique advantage due to their structured social environment and strong value-based education system, which can facilitate the internalization of sustainable practices (Lalander et al., 2019).

Another critical dimension is the potential scalability and replicability of the model beyond pesantren settings. Given its low-cost technology and reliance on locally available resources, maggot-based waste management can be adapted to other community institutions such as schools, rural cooperatives, and urban neighborhoods. However, scaling up requires standardized operational guidelines, technical support, and policy alignment to ensure consistent quality and environmental compliance. The development of pilot projects and demonstration sites can serve as effective strategies to showcase best practices and encourage wider adoption (Diener et al., 2011).

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Finally, the integration of digital technology and innovation presents new opportunities to enhance the efficiency and outreach of maggot-based systems. Digital platforms can be utilized for marketing, knowledge sharing, and monitoring production processes, thereby improving transparency and market access. Additionally, incorporating data-driven approaches in waste management planning can optimize resource utilization and strengthen decision-making processes. By leveraging both traditional community values and modern technological tools, maggot-based organic waste management can evolve into a more resilient and future-oriented system (van Huis, 2020).

Conclusion

The findings of this study indicate that the general condition of waste management in Islamic boarding schools (pesantren) remains relatively basic and varies across institutions. In several pesantren, such as Asshomadiyah and Al Aziziyah, waste management practices are still characterized by the simple collection of waste in a single disposal point without proper segregation between organic and inorganic materials. This approach reflects a conventional and linear waste management system that limits the potential for resource recovery. In contrast, other pesantren, including Nurul Kholil and Nurul Amanah, have initiated waste separation practices by distinguishing organic from inorganic waste. However, these efforts remain suboptimal, as the separated waste has not yet been effectively processed into value-added products with economic benefits.

The results of the business feasibility analysis demonstrate that maggot-based organic waste management in pesantren is economically viable across multiple dimensions, including technical feasibility, human resource capacity, and market accessibility. From a financial perspective, the maggot cultivation business shows strong profitability potential, supported by relatively low operational costs and stable market demand for its derivative products. The level of income generated is directly proportional to the volume of organic waste processed, indicating that scalability plays a crucial role in maximizing economic returns. These findings suggest that pesantren possess significant potential to transform organic waste into a sustainable source of revenue while simultaneously addressing environmental challenges.

Furthermore, the management of maggot-based organic waste processing follows the four fundamental management functions: planning, organizing, actuating, and controlling (POAC). Effective implementation of these managerial components is essential to ensure operational efficiency and long-term sustainability. The planning stage involves waste mapping and system design, while organizing focuses on establishing clear institutional roles and responsibilities. The actuating phase emphasizes practical implementation through maggot cultivation processes, and the controlling phase ensures continuous monitoring and evaluation to maintain adherence to standard operating procedures.

In addition, this study proposes an integrated eco-edutourism model as an innovative extension of maggot-based waste management in pesantren. The model combines tutorial-based learning with on-site experiential exploration, enabling visitors to gain both theoretical knowledge and practical insights into organic waste processing. This approach not only enhances environmental awareness but also creates new opportunities for educational engagement and alternative income generation. Overall, the integration of

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waste management, education, and tourism presents a holistic and sustainable framework for addressing organic waste challenges in pesantren environments.

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