

SUSTAINABLE REARING OF BLACK SOLDIER FLY: METHODS AND BENEFITS

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ABSTRACT Rearing of black soldier flies (*Hermetia illucens*) has emerged as one of the sustainable solutions in the management of waste with the production of high-quality animal feed. It will discuss the biology and the life cycle of black soldier flies, focusing on their competence in organically decomposing waste and creating high-value biomass. The larvae decompose waste efficiently to reduce its volume, and greenhouse gases and hence contribute to environmental sustainability. With higher protein and fat content, black soldier fly larvae are indeed an alternative feedstock that stands competitive against the traditional for livestock, poultry, and aquaculture feedstock. These include disease management and scaled production. Innovative approaches indeed hold real promise toward integrating black soldier fly into circular economy models to improve food security and local economies.

Keywords: Flies; Bio-economy, Nutrient recycling, Poultry feed; Sustainability

INTRODUCTION

Black soldier flies are often known for two-fold application in the sustainable management of wastes and are rich in nutrients as animal feed. Indeed, with their capacity to transform organic wastes into high-quality proteins and fats, black soldier flies to make them an essential element of the circular economy in addressing food and environmental security.

Efficiency to Reduce Waste

Black soldier fly larvae decompose organic waste up to 84.5% and therefore treat many materials, such as vegetable and restaurant wastes (Amin, Lando et al. 2024). Their fast consumption of organic waste further helps to minimize landfill volumes and decrease methane emissions; the practice favors environmental sustainability (Tepper, Edwards et al. 2024).

Nutritional Worth and Utilization

Black soldier fly larvae contain 9.25 to 10.69 g/100 g of protein and 3.29 to 15.90 g/100 g of fats which makes it suitable for animal feed. All the nutrients are present in the organic manures produced by the larvae, which improves the general quality of the soil and agricultural productivity (Pradabphetrat, Sathawong et al. 2024).

Economic and Environmental Benefits

The inclusion of black soldier fly in food systems has actually saved resources while promoting ecological stewardship, consequently, it forms a circular economy that is beneficial both to agriculture and waste management. (Odongo, Bbosa et al. 2024) Future research will focus on enhancing capabilities in the biotransformation of wastes by black soldier fly as well as their potential application in high-value biomolecule production. With all these benefits accrued from black soldier fly farming, another critical issue involves optimization of the rearing conditions and producing on an industrial scale in order to maximize their impact on sustainable agriculture and waste management.

Sustainable Rearing Methods:

The art of raising black soldier flies in an environmentally friendly way has received immense recognition over the last few years because this opens up the opportunity to transform organic waste into excellent products like proteins, fats, and bio fertilizers. Sustainable ways reduce resource inputs, environmental impacts, and maximize yields. To this extent, a number of techniques have been devised and optimized so that black soldier fly farming can be assimilated into circular economies with minimal ecological footprints. Organic wastes mixing has been promisingly optimized the performance of

black soldier fly larvae (BSFL) in sustainable waste management. It has been shown that the different substrate mixes improve growth, promote waste reduction more efficiently, and render BSFL to adapt to various local waste streams.

Substrate Optimization:

The mix of the protein-rich substrate such as soybean curd with carbohydrate sources like coconut endosperm enhances growth as well as waste reduction strongly of black soldier fly larvae (Pliantiangtam et al., 2024). Co-digestion of mushroom root waste with soybean curd residues improves nutrient availability, thus leading to higher bioconversion rates and protein content in the larvae.

Benefits of Waste Management

Black soldier fly larvae successfully reduce organic waste by up to 84.5%; they thus suggest their possibility in handling all forms of waste. (Amin et al., 2024) The larvae do not hold any toxins in the low-quality waste that they consume; thus, it is suitable for processing difficult organic waste streams.

Circular Economy Contributions

Feed is the source of organic waste that larvae consume, and they produce valuable products like insect meal and frass, which serves circular economy purposes to get rid of resource-intensive feed sources. (Okeyo, Wandera, & Messo, 2024) Generally, there are many advantages of managing waste from black soldier fly larvae but still challenging to optimize various substrate combinations and scaling-up the production system to meet the increasing needs in waste management.

Benefits of Black Soldier Fly Rearing:

Ecological, nutritional, and economic benefits in raising black soldier fly. The practice of the black soldier fly rearing provides several ecological, nutritional and economic benefits. It is indeed a sustainable way toward waste management, high-value sources of protein and fat for the animal feed chain can be ensured and further, it can provide employment and business opportunities at local levels.

Waste Management

Black soldier fly larvae have proven to be potent converters of organic waste into biomass. Therefore, black soldier fly larvae could offer a solution to the high volumes of agricultural and food wastes. The larvae reduce waste volumes by up to 50-70%, massively reducing the volume of organic matter that would otherwise find its way to landfills (Lalander et al., 2013). This bioconversion process reduces pressure on waste disposal systems besides, it minimizes the production of harmful greenhouse gases such as methane, which is a byproduct of decomposition produced by organic wastes in landfills. Traditionally, most of the environmental impacts associated with waste disposal through landfilling or incineration are mitigated by converting food waste, manure and other organic by-products into valuable protein and fertilizer through black soldier fly farming (Diener et al., 2011). Moreover, since the larvae can

process a variety of low-quality organic waste streams, they help divert materials which are normally challenging to manage.

Nutritional Value

Black soldier fly larvae contain a high protein and fat content and form an ideal feed for livestock, poultry and aquaculture. The protein in the larvae is estimated to be about 40–45%, while the fat content is about 30–35% on a dry matter basis. This is in a conformity with the accepted animal feed conventional sources such as fishmeal as well as soybean meal (Barragan-Fonseca, Dicke, & van Loon, 2017) (Bibi et al., 2024). Further, black soldier fly larvae is abundant in all the essential amino acids and essential fatty acids that assists in putting nutrients into place in feed mix. These larvae can generate proteins and fat of higher yields and clearly make for a very healthy replacement for more expensive soy and fishmeal. It also has a further capacity of lowering the additional pressure placed on the already overused wild fish stock that is being reared for fish meals and lessens the area and water usage for soybean production.

Applications in Animal Feed and Aquaculture

Black soldier fly larvae are increasingly being valued in, poultry and swine feed and in fish as well. Interestingly, the larvae contain good nutritional value that makes it a potential feed that can actually compete or supplement other commonly used protein sources. The apprenticeship of black soldier fly larvae meal in growing broilers and fish feed has also been reported to enhance their growth performance and improved feed conversion more so reducing the use of costly feedstuffs which are in-effective in sustainable production the world over (Henry, Gasco, Piccolo, & Fountoulaki, 2015). Black soldier fly larvae has therefore been considered a good partial replacement for fishmeal which is extremely costly and cannot be supported under the current ecological conditions. There is evidence that replacement of fishmeal with black soldier fly larvae meal in diets does not reduce the quality indicators of the growth and health of fish species, such as tilapia and salmon, (Makkar, Tran, Heuzé, & Ankers, 2014). Thus, black soldier fly larvae is an important resource that can help in the quest to achieve sustainability in aquaculture—an increasingly fast-growing industry.

Challenges and Solutions:

While it has several benefits associated with the rearing of black soldier fly's challenges have also been experienced and these affect its spread and sustainability. Addressing such challenges using innovation and the advance of research is very crucial for black soldier fly larvae to be successfully integrated into waste management systems and food production.

Disease Management

With regard to black soldier flies, the health and productivity of its larvae in mass cultures are greatly affected by disease outbreaks. These may include bacterial, fungal and viral infections, which often lead to a reduction in growth rates, increase in mortality and decreased efficiency in the conversion

of organic waste. Commercial production could have to rely on very dense rearing environments, which encourages the spread of pathogens. Consequently, disease control assumes an imperative function in the expanded macro-organism cultivation of black soldier fly larvae. In addition, adverse bacteria in the substrates that is being used for the rearing of the larvae have implications health wise to the larvae and humans. Epidemiological risk factors could be minimized by proper sanitation practices, handling and treatment of the substrate and some biosecurity measures in an effort to cut short these risks (Diener, Zurbrugg, & Tockner, 2009).

Application of Automation and Technology

The use of robotic process in the rearing of black soldier flies escalates the practice as it becomes easier to practice. It is therefore possible to optimize feeding; other factors such as climate control and monitoring technologies can enhance environmental conditions; these can influence the environmental conditions and prevent additional costs of labor on black soldier fly larvae. These ensure that producers sustain the laid down growth rates while increasing the conversion efficiencies the more scales are applied. Data analytics and artificial intelligence are also applied in feeding regimes and health indicators of larvae, growth trends of which are also predicted so as to enhance productivity (Lohri, Diener, Zabaleta, Mertenat, & Zurbrugg, 2017). It also promotes change in response to the prevailing conditions hence improving operation activity.

Future Opportunities of Rearing Black Soldier Flies:

In terms of growth and compatibility in sustainable food systems and practice in waste management the opportunity of rearing black soldier flies is rather very promising. That is why it is crucial to find out the possible research gaps and applications of the circular economy model in order to enhance the advantages of black soldier fly larvae farming.

Research Gaps and Opportunities

There are so many gaps and opportunities in research on sustainable rearing of black soldier fly. Perhaps one of the key areas in this context would be disease management. Black soldier fly is generally robust, but yield loss and other biosecurity risks may arise at larger-scale production. Thus, there is a strong need for research on microbial interaction, immune response, and other prevention measures. This brings another challenge related to scale. Small-scale methods adopted to date need to be scaled up to industrial level with a focus on cost-effective and automated systems for feeding, waste processing, and larvae harvesting (Smetana, Schmitt, & Mathys, 2019). In addition, the nutrient profile of black soldier fly larvae is largely dependent upon the feedstock they consume; thus, identification of optimal feedstock enhancing protein and fat levels, ensuring uniform nutritional profiles for animal feed, requires more research.

Nutritional and Functional Profiling

Additional research is needed in order to further outline the nutritional composition of black soldier fly larvae regarding the type of substrates used. Knowledge of how different organic

waste feeds impact the nutrient content of the larvae will make it possible to tailor feeds for specific livestock or aquaculture applications (Barragan-Fonseca et al., 2017). Furthermore, research on black soldier fly larvae bioactive compounds and their health-promoting qualities may unlock new applications of the insect using the insect in functional foods or nutraceuticals.

Environmental Impact Assessment

Although earlier studies have shown that black soldier fly larvae farming is environmentally friendly, it is still necessary to conduct comprehensive LCAs to ascertain the general ecological footprint of the production of black soldier flies. Some research areas should include the carbon and water footprint of black soldier fly larvae farming relative to other protein sources and its possible contribution to greenhouse gas mitigation.

Waste Valorization

Black soldier flies play a significant role in waste valorization wherein organic waste is converted into useful products such as protein-rich larvae, fat, and organic fertilizer (Diener et al., 2009). The use of agricultural by-products, food waste and organic residues as feedstock for black soldier fly larvae can close nutrient loops, effectively reducing landfilling and incineration for waste disposal. This means that it contributes to environmental sustainability and generates new economic opportunities for handling waste.

Challenges and Solutions:

The problem areas namely disease and how to overcome them when growing black soldier fly larvae, as well as how to expand the scale of production have been determined. Such problems require new approaches and technologies for solving and improving production efficiency, using automation and probiotics.

Future Directions:

It is necessary to determine the existing research gaps and the possibility of using black soldier fly larvae in the circular economy systems. A value addition on wastes is done by black soldier fly larvae farming that is much more significant in making sure that sustainable animal feed production is done hence enhancing the resilience of the supply chain system. There can be little doubt, therefore, as to the vital contribution that black soldier fly rearing holds for sustainable agriculture. In combination with the ability to feed on organic waste, black soldier fly larvae farming offers an opportunity to meet livestock feed demand in a sustainable manner that reduces the detrimental effects caused by the production of conventional feeds. Furthermore, the use of black soldier fly larvae in waste management is in consonant with circular economy where waste stream is reduced and resources utilized optimally. (Salomone et al., 2017).

This becomes more important as food demands rise around the world and the stresses placed on farming and production. Rearing Black soldier fly has been proposed to be an effective solution to these challenges in terms of food security, environmental conservation as well as helping the local

economy. Future advancement in this area will be critical to fully unlocking the opportunities of black soldier fly larvae farming and promoting a better green agriculture system.

CONCLUSION

Black soldier fly farming is a way of rearing organic and sustainable means of disposal of wastes and an excellent source of protein and fat for animals. It involves helping in conversion of waste into bio-resources for feed in circular economy system, not landfill and green gas emissions. The nutritional contents of the larvae make it a potential feed replacement in livestock, poultry and aquaculture systems. Other associated issues with disease management and scaling up production, though being progress-managed only through ongoing research and innovation will yield the maximum potential benefits to black soldier fly farming in environmental and economic profit and, therefore, promote food security and sustainability. Embracing a diet enriched with antioxidants from wheat and other whole grains represents a practical health choice, shielding individuals from the risks associated with chronic diseases and promoting overall vitality.

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