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A Study on the role of *Hermetia illucens* (Diptera: Stratiomyidae) as a bioconversion agent

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Abstract
The effectiveness of the Black soldier fly, *Hermetia illucens* larvae in the bioconversion of four types of organic wastes, including organic debris, vegetable waste, fish waste, and chicken waste was assessed. In addition, the effects of various organic wastes on *H. illucens'* life cycle, larval growth, and weight gain were evaluated.

Keywords: *Hermetia illucens*, bioconversion efficiency, waste reduction index, substrate reduction

Introduction

The rapid urbanisation, population growth, and economic advancement of nations that demand high-quality meals and the management of organic waste would require a lot of resources [1, 2]. Between 2013 and 2050, agricultural production has to expand by 49% to meet this need [1]. Worldwide, especially in developing nations, enormous amounts of organic waste are being produced and are improperly managed [3, 4]. Large-scale daily production of municipal solid trash results in significant environmental issues [5]. The recycling of different types of garbage and other accumulated nutrients in our environment is greatly aided by insects. Utilization of *Hermetia illucens* author name and year for the bioconversion of organic wastes is one such strategy [6]. *H. illucens* belongs to the Order Diptera and family Stratiomyidae and popularly known as the black soldier fly (BSF).

Another major global challenge is the growing demand for animal fodder which may not be produced satisfactorily from those resources that are naturally available. A solution that is feasible to overcome this challenge is the application of feed that is produced from insects [7]. About 37- 63% protein and up to 49% fat are present in BSF larvae along with some micro and macronutrients that are essential for animal growth, and development as well as for human nutrition [8]. The price for the feed can be minimized by promoting the use of good quality insect-based feed which may in turn boost productiveness. The frass that *Hermetia illucens* larvae produce has the capacity to recover Nitrogen and Phosphorus from the food chain and reuse it as fertilizer, thereby minimizing the demand for chemical fertilizers [9].

This study investigated the effectiveness of BSF larvae in the bioconversion of four distinct organic wastes, which include vegetable, fish, poultry wastes, and organic debris, as well as the impact of these organic substrates on the survival, weight gain, and growth rate of BSF larvae and their life cycle.

Materials and Methods

The present study followed the experimental methods described by Nguyen *et. al.*[10].Organic debris, vegetable waste, chicken waste, and fish waste were the different types of waste given to BSF as the diet in this study. In order to make a consistent homogeneous diet, large quantities of each organic waste were crushed with the help of a shredder [10].

About 50 four-day-old BSF larvae were kept in each 12 square-shaped containers made of glass without lids and added 6 grams of waste from each type of waste to these containers. The square containers measured about 30 x 30 x 6.5 cm and are sealed properly with the help of good quality muslin cloth and rubber bands so that larvae cannot escape outside and to prevent other flies or insects from causing any kind of infestation or decay. The glass containers should not be placed directly under the sunlight. 50 BSF larvae in three sets of control replicates were simultaneously fed and larvae were removed from the containers on the alternative days in order to weigh and record the remaining waste left in the containers. Out of three sets of replicates, the first and second were labeled as handled, and unhandled, and no larvae were placed in the third set. The third set of replicate was set up in order to determine the amount of waste diet being reduced due to evaporation and bacterial decomposition. The dehydration loss was taken into account while calculating the rate of reduction of waste by the activity of BSF larvae. 6 grams of waste were newly added to each container on a regular basis. On the alternative days of study, those larvae in the handled sets were taken out, the remaining waste diet was weighed and recorded. The amount of diet was increased by 5 grams when the wet weight of provided feed reached 25%. The experiment was stopped when 40% larvae of the handled set attained the wandering stage of their life cycle. Same quantity of waste diet was also added to the second and third sets, then the mortality rate, rate of survival, and weight gain of BSF larvae were noted when 40% of larvae in the first set reached their wandering stage. The larval weight of 5 samples consisting of ten larvae each was measured with the help of an electronic weighing balance.

The parameters measured include the rate of survival, Waste Reduction index, larval growth rate, and weight gain, percentage of substrate reduction, and Efficiency of Conversion of Ingested food. The mathematical formulas applied in the calculations were described in Jucker *et. al.* [11].

Results

Waste Reduction Index (WRI)

For each waste type, the Waste Reduction Index (WRI), which measures how efficiently larvae can reduce their feeding substrates, was determined. The higher the value, better the efficiency with which larvae can reduce organic matter. Since no larvae survived in the given feed during the experiment, the fish waste-fed larvae were not included in the calculations. The maximum mortality of larvae fed on fish waste may be caused by heavy metal presence [10].

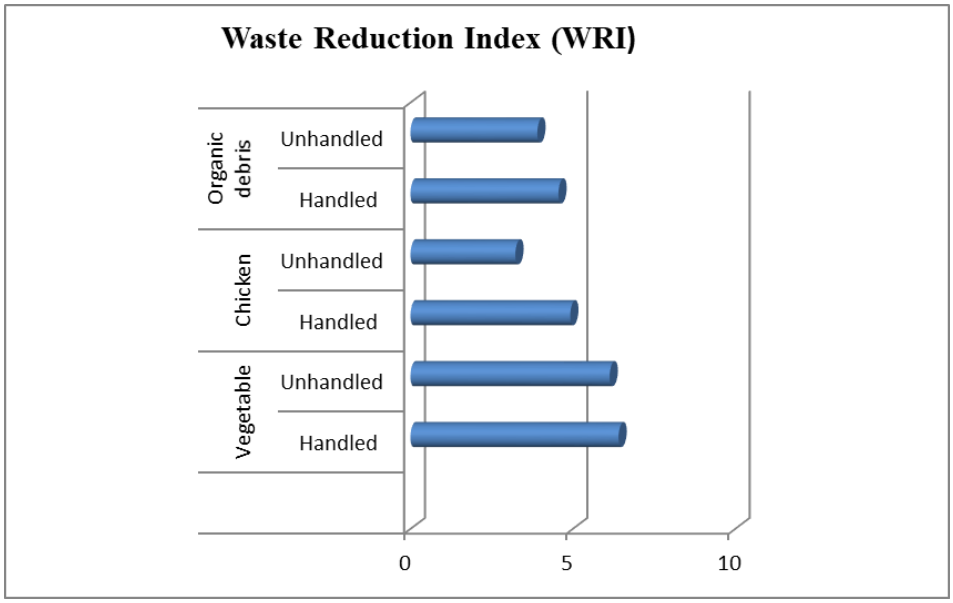

Fig 1: Waste Reduction Index

Rate of survival of BSF larvae

In three organic wastes, the mean percentage of survival rate from the four-day stage to the prepupal stage varied with a maximum survival rate in vegetable waste, followed by chicken waste and then organic debris (Table 1).

Larval Growth Rate

The larvae fed on the chicken waste recorded the highest growth rate followed by vegetable waste and then organic debris (Fig.2).

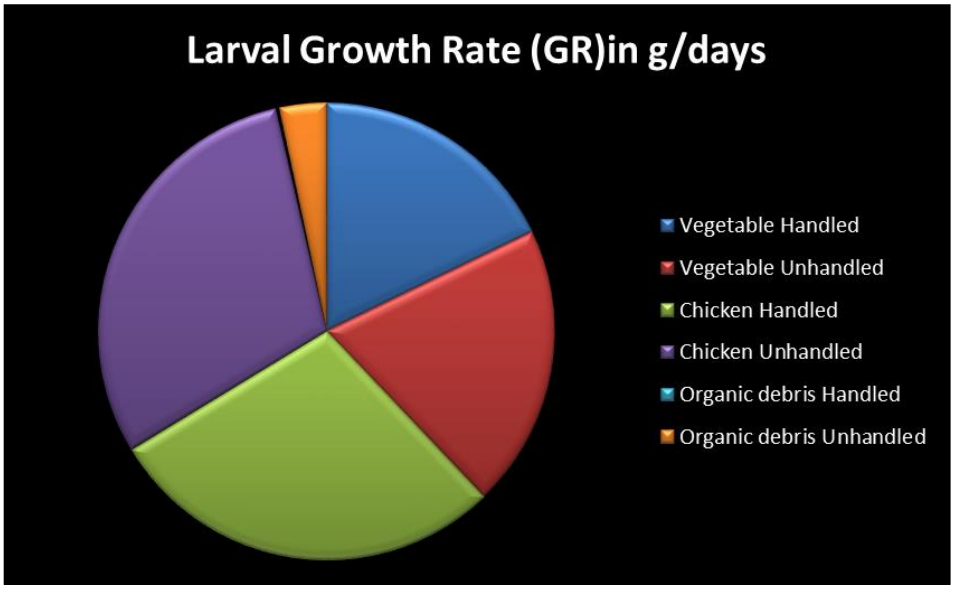

Fig 2: Larval growth rate in mg/days

Efficiency of Conversion of Ingested food (ECI) and larval weight gain: The highest ECI value and larval weight gain were obtained in the larvae fed on chicken waste followed by the vegetable waste and organic debris (Fig. 3).

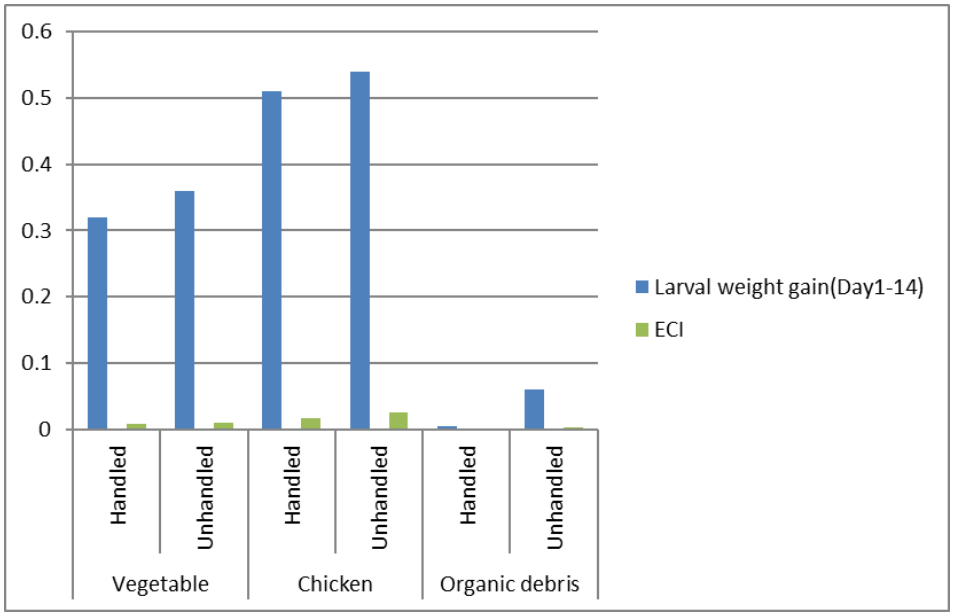

Fig 3: The Efficiency of Conversion of Ingested food by BSF larvae and larval weight gain (Day1-14)

Substrate Reduction (SR)%: The vegetable waste recorded with the highest SR% followed by chicken waste. The minimum substrate reduction was observed in the organic debris (Fig. 4).

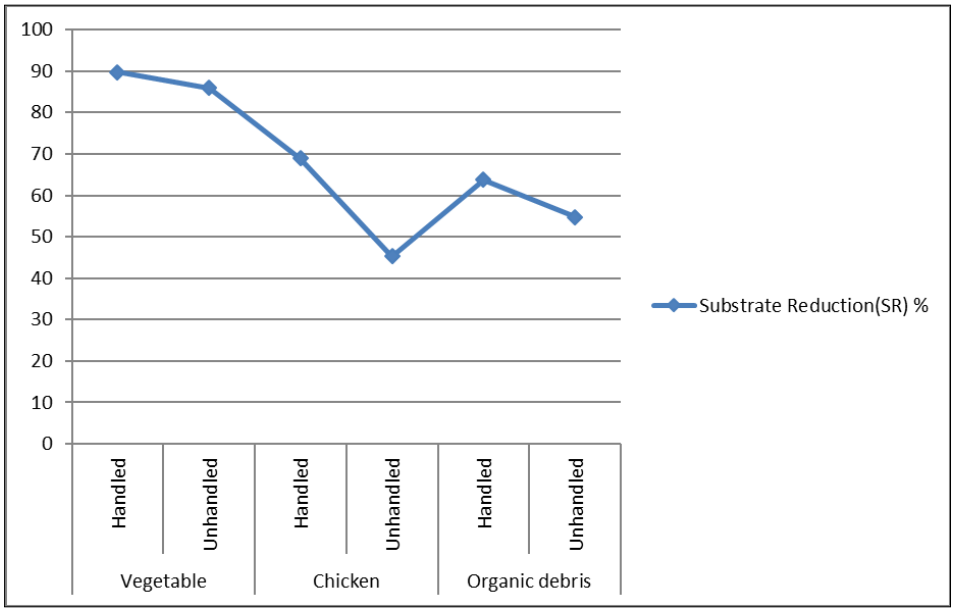

Fig 4: Substrate Reduction (SR)%

Table 1: Results obtained from the experiment conducted

Type of waste		Vegetable		Chicken		Organic debris	
		Handled	**Unhandled**	**Handled**	**Unhandled**	**Handled**	**Unhandled**
Waste Reduction Index (WRI)		6.4078	6.1342	4.9209	3.2314	4.5571	3.9078
Survival Rate %		82	90	60	68	36	36
Larval Weight Gain	Initial Larval weight (in milligrams)	0.0212	0.0186	0.0212	0.0186	0.0140	0.0164
	Final Larval weight (in milligrams)	0.3407	0.3785	0.5315	0.5576	0.019	0.077
Larval Growth Rate (GR)in mg/days		0.0228	0.0257	0.0364	0.0385	0.0003	0.0043
Efficiency of conversion of digested food (ECI)		0.0080	0.0093	0.0164	0.0262	0.0006	0.0029
Substrate Reduction %		89.71	85.88	68.89	45.24	63.80	54.71

Discussion

The efficient bioconverter, *Hermetia illucens* larvae is a rich source of protein and fat and have uses in the biochemical and animal feed industries. It can thrive on a variety of different organic sources such as vegetable waste, chicken waste, organic debris, etc. The fly's ability to drastically minimize waste offers an opportunity to create a circular food economy [11]. The BSF larvae must be fed with diets having higher levels of fat and energy to complete their growth [12] because the adult BSF does not ingest food [13].

This study evaluated the effectiveness of waste reduction and bioconversion as well as how different rearing

substrates affected larval growth as measured by the total weight the larvae gained during the experiment from the four-day larval stage to the prepupal stage. The amount of waste diet reduced and the rate of bioconversion significantly varied among different organic wastes. The BSF larvae fed on the vegetable waste had the highest Waste Reduction Index as it took the longest time to develop to the wandering stage. BSF larvae exhibited growth on all substrates provided except fish waste and those larvae fed on the chicken waste exhibited a maximum rate of growth than the vegetable waste and organic debris. Due to the heavy metal accumulation, the highest mortality rate was recorded in the fish waste-fed BSF larvae.

The rate of survival of BSF larvae was highest in the vegetable waste which varied in both unhandled and handled setups with unhandled conditions having more survival rate. The heaviest BSF larvae were developed in the high-calorie and fat-containing chicken waste. Among all organic wastes provided, the larvae grown in the organic debris recorded the lowest weight gain as it probably consists of the lowest fat and energy content compared to other substrates.

This study also assessed the life cycle of the BSF where it took approximately 40-45 days to complete its life cycle and even though different organic substrates were provided to BSF larvae, there were no significant differences noted in the duration of their life cycle. The mating and oviposition occur only once in the lifetime of an adult female [14], where they lay eggs in the crevices available near to the substrate provided and the eggs hatch within 4 days [15]. The four stages in the growth cycle of BSF include egg, larva, pupae, and adult where the larvae fed with the organic substrates can attain an approximate weight of 220mg[16]. Adult fly characteristics can also be affected by the nutrition provided during their larval stage [17]. Maggots migrate away from the food source once they had ingested an adequate amount of food for the pupation to begin [18] and depending upon temperature and ambient humidity, the duration of the pupal stage may last from five to seven days. The future scope of *H.illucens* in the bioconversion of different organic wastes is revealed through the present study.

While the application of insects is regarded as an alternative strategy to reduce the effects of increasing population and climatic changes, *H. illucens* proves to be the best choice among the pantheon of one million species by providing ecological as well as economic services along with the bioconversion of waste substrate [19]. The economic, ecological, and social sustainability can be assured by promoting more research and projects related to bioconversion applications of *H. illucens.*

Conclusion

The current study validates the black soldier fly's ability to be used in solid waste management. *H. illucens* is a very resilient species due to its capability to adapt to harsh environmental conditions including a lack of food, inadequate oxygen levels, drought, etc. Extreme weather patterns, unprecedented economic growth, urbanization, population growth, the high environmental footprint of agricultural practices, and disposal-oriented waste management practices necessitate significant changes in how we produce food, feed, and fuel as well as how we manage the disposal of massive amounts of organic waste, particularly in low- and middle-income countries. It is possible to produce nutrient-rich animal feed, fuel, organic fertilizer, and biobased products along with eco-friendly waste decomposition by raising insects like *H.illucens* on a variety of organic wastes. The inclusion of BSF larvae/pupae in the diets of chicken, fish, and pigs have shown promise as a potential replacement for traditional feed ingredients such as fish meal and soybean meal. Additionally, the bioactive substances present in BSF larvae and pupae, like antimicrobial peptides, medium chain fatty acids, chitin, and its derivatives, may enhance the nutritional content of animal feeds [11].

The waste bioconversion approach by utilizing insects like *H.illucens* represents a joint economical, sustainable, and eco-friendly solution to confront the protein demand for aqua-feed as well as other animal feeds in the future and is also considered as a sustainable biotechnological approach for the organic waste management [20]. BSF farming offers a lot of employment opportunities for those vulnerable populations especially women, young farmers, unemployed youth, etc. in economically backward nations as it requires only minimal resources and capital investment [21]. Therefore, the introduction of even small-scale BSF units in every house can ensure safe, an eco- and budget-friendly method for organic waste management as well as proper household waste recycling without causing any kind of harm to the environment.

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