

Influence of Organic Substrates on Performance of Black Soldier Fly Larvae (*Hermetia Illucens*) BSFL)

Maphios Mpofu*, Primrose Nkomboni, Givious Sisito, Theresa Rukuni, Tendai Dominic Matekenya, Siphathiwe Sibanda and Killion Ndebele

Department of Livestock Research and Innovation, Matopos Research Institute P. Bag K5137 Bulawayo, Zimbabwe

ABSTRACT

The bioconversion process of food waste using Black Soldier Fly (BSF) has been considered an effective way in degrading and adding value to organic waste. This process produces larvae as feed resource and solid residue as compost (frass). A total of 10 000 individual larvae at 3 days old were used to conduct the trial, and were randomly allocated to four treatments diets. The plastic trays were used, each tray contains 500 larvae of average weight of 100mg and were fed with 600g of substrates from different sources, each treatment replicated five times. The study was conducted to determine the effects of Black soldier fly larvae reared on market waste, restaurant waste, pig dropping and poultry dropping on larval survival rate, final weight, waste reduction percentage, waste reduction index (WRI), efficiency of converting digestible feed (ECD), feed conversion ratio (FCR) and (frass) production. The 3 day old larvae were fed for 12 days and the results indicated that larvae reared in market waste has highest larval weight 296±41mg per larvae, waste reduction percentage 48.55±1.3%, Waste reduction index 10.2±0.68%, and ECD, 63.2±6%, (P<0.05). Highest frass production was observed, to larvae reared in restaurant waste 332gDM frass and FCR 44.5 was significantly high (P<0.05) than other treatments. The survival rate was not (P>0,05) significantly influenced by treatments. These results provide valuable insights for utilizing organic waste in BSFL rearing, contributing to the development of more sustainable waste management, animal feed and organic fertiliser production methods.

*Corresponding author

Maphios Mpofu, Department of Livestock Research and Innovation, Matopos Research Institute P. Bag K5137 Bulawayo, Zimbabwe.

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Introduction

The world population is increasing and the general increase in demand for natural resources have had a negative impact on all life on earth [1]. One of the huge challenges in almost all the cities in Africa is waste management. In cities the amount of waste in had reached 5,064.88 tons/day consisting of 43.24% food waste, 17.73% wood branches and leaves, and 39.03% inorganic waste. Ovuru et al With the fast urbanization and agricultural land transformation into accommodation generating organic waste in a short period of time in some areas and the growing population, an upsurge in waste has become issue in developed and developing countries and may shortly become the most prominent concern for the world [2-3]. The food supply chain is generating 1.3 billion tons of agricultural and food waste every year Jones and Tomberlin [4]. Currently, waste production and improper management is responsible for production of 1.6 billion tons of carbon and methane emission. the depletion of natural resources, the increase in use of valuable land use for human settlements and other activities and continuous generation of waste are detrimental to our planet Broeckx et al [1]. More sustainable alternatives to guarantee a sufficient supply of food, feed, and biomaterials are needed.

One of the alternatives that may hold an interesting position in a circular economy is the implementation of insects. Brian et al As insects have proven to be able to efficiently convert low-value biomass into their own biomass consisting of high-quality

components (i.e., proteins, fats and chitin, they have the potential to help tackle the societal challenges [5]. Using insects for food, feed, biomaterial production, and to valorise side-streams is a strategy that has gained increased interest Laganaro et al [6]. Black soldier fly (*Hermetia illucens*) larvae can convert bio-waste and by-products into body mass high in protein (>40% dry matter, DM) and lipid (30% DM). However, the type of rearing substrate also affects the larval body composition and thus its nutritional value. Numerous studies have researched the use of bio-waste and by-products for rearing BSF larvae such as animal manure, brewery by-products, fish offal, and fruit and vegetable waste. These studies have shown that the larval composition and performance are largely modified by the rearing substrate. However, there is so far a limited and contradictory understanding of the relation between substrate and larvae nutrient composition. Surendra et al The larvae are able to reduce various types of organic waste up to 35-45% of the total waste weight and able to decompose up to 68% of urban waste, 50% of chicken manure, 39% of pig manure and 25% of a mixture of chicken and cattle manure [7]. It is due to several bacteria found in the digestive tract of black soldier larvae which capable of producing digestive enzymes such as amylase, protease, and lipase to hydrolyse the substrate for then used it as feed. This study aimed to determine the ability of larvae in converting market waste, restaurants waste, poultry droppings and pig manure based on the larval growth rate, larval mortality, WRI (waste reduction index), ECD (digestible feed efficiency) and nutrient performance of larvae from different substrates.

Materials and methods

The experiment was conducted at Matopos Research Institute at Livestock Nutrition section. The eggs of black solder fly were obtained from insectary cage and incubated for five days, then the larvae used for the experiment was collected at three days old, physically counted and weighted. The larvae were randomly allocated in to four different organic waste that is Market waste, pig manure, restaurant waste and poultry droppings. The larvae were reared in the plastic trays each trays containing 500 individual larvae with an average weight of 100mg. the substrate were collected from different places, market waste were collected from Bulawayo market, restaurant waste were collected from Rhode preparatory school where as pig and poultry droppings were collected from Institute. Each treatment was replicated five times containing 2500 larvae. Feeding was done every after four days with addition of 600g of new substrates. The experiment lasted for 12 days, the larvae from each tray were counted, weight and recorded. The larvae were taken to the laboratory for proximate composition analysis. The amount of frass were also weighed and recorded. Observation parameters consisted of larval final weight, feed conversion ratio FCR, frass weight in dry matter, substrate reduction percentage, waste reduction index (WRI) and digestible feed efficiency (ECD), as well as larval survival rate.

The frass quantity test was carried out by weighing the frass produced from each variation. Several aspects related to the calculation of the compost quantity can be seen as follows: Waste reduction index (WRI):

$$WRI = \frac{D}{t} \times 100, \quad \text{where } D = \frac{W-R}{W} \times 100$$

Results

Table 1: Growth performance (fresh live weight), Waste Reduction Index (dry matter) and Efficiency of Conversion of Ingested substrate (dry matter) of BSF larvae grown on four different substrates

Parameters	Treatments				SEM	P. Value
	Market Waste	Restaurant Waste	Pig Droppings	Poultry Droppings		
Larvae I.W (mg)	106.2±1.6	98.3±5.0	105.6±1.6	108.1±1.6	2.7	0.698
Final Weight (mg/larvae)	295.6±41.4 ^a	248.03±27.2 ^{ab}	233.07±35.5 ^{ab}	129.9±9.7 ^b	22.5	0.001
Survival rate(%)	85.5±8.26	70.5±15.5	82.2±5.7	78.5±6.9	4.5	0.711
Substrate Reduction(%)	48.55±1.34 ^a	41.57±5.6 ^{ab}	28.94±3.24 ^b	26.55±3.1 ^b	3.12	0.008
WRI(%)	10.7±0.5 ^a	9.3±0.67 ^{ab}	6.1±1.25 ^{bc}	5.03±0.32 ^c	0.45	0.003
ECD(%)	63.2±6.0 ^a	12.3±2.9 ^b	16.0±1.29 ^b	8.2±1.92 ^b	1.69	0.001
Frass Weight (g) (DM)	184.8±7.14 ^b	662.6±28.1 ^a	602.3±47.1 ^a	208.6±14.4 ^b	33.9	0.001
FCR	20.37±2.6 ^b	20.40±1.7 ^b	39.37±1.2 ^a	44.56±3.6 ^a	4.51	0.018

I.W=Initial weights, WRI= waste reduction index, ECD=efficient of conversion of ingested feed, FCR=feed conversion ratio, a–c Means with different letters in a row are significantly different (p<0.05). P=probability; SEM= standard error mean.

Table 3.1, indicate that the larval growth was significantly high to larvae reared in market waste and lower growth rate was observed chicken dropping. Highest substrate reduction percentage was reported market waste significantly(P<0.05) high. Waste reduction index (WRI), feed conversion ratio (FCR), was significantly (P<0.05) high in market waste and restaurant waste which significantly improved than other substrates consumed. The highest efficiency of conversion of digested feed was observed in market waste. Organic fertilizer production was high P<0.05) in restaurant waste and pig droppings. This shows that survival rate was not significantly (P>0.05) influenced by substrates used.

Waste reduction index $D = \text{substrate reduction percentage}$

(1) Where D is total feed reduction(gram), W is total feed (gram), R is total feed remaining after a specific time (gram), WRI is waste reduction index (%/day), and t is total time larvae eat feed (days). ECD is the efficiency of digestible feed that is digested by larvae during the raising period. The digestible feed efficiency was calculated using equations:

$$ECD = \frac{B}{I-F} \times 100\%$$

where: ECD = digestible feed efficiency, B = dry weight of the biomass formed (dw), I = initial weight of substrate (dw), and F = dry weight of casting (unconsumed food + excreted waste) (dw). The **survival rate** is the percentage of the initial number of larvae compared to final live larvae which can be determined using the equation:

$$SR = \frac{N}{n} \times 100$$

Where SR= percentage of final larvae, N = total number of final live larvae, and n = total initial number of larvae.

Data analysis

All experimental data including initial and final weight of larvae of every substrate were recorded in an Excel spreadsheet after which analysis was carried out. All the data were analysed using one-way analysis of variance (ANOVA) General Linear Model. Comparison of means between groups was done by Tukey's HSD test. Statistical differences were considered at a significance level of (P<0.05). Data were analysed by Statistical Package for the Social Sciences (SPSS) version 20 for Windows.

Table 2: Effects of substrate on proximate composition of black soldier fly larvae grown in different organic substrates. a–c Means with different letters in a row are significantly different (p<0.05); P=probability; SEM= standard error mean

Parameters (%)	Treatments				SEM	P. Value
	Market waste	Restaurant waste	Pig Droppings	Poultry Droppings		
Larvae I.W (mg)	44.7±1.17 ^a	31.4±2.12 ^b	45.67±1.4 ^a	41.52±2.33 ^a	0.94	0.001
Final Weight (mg/larvae)	8.29±0.89 ^b	5.9±0.99 ^a	10.24±0.84 ^b	10.20±0.96 ^b	0.43	0.038
Survival rate(%)	48.20±1.12	48.7±1.37	51.4±0.99	49.2±1.18	0.63	0.340
Substrate Reduction(%)	19.18±1.02 ^b	35.6±2.14 ^a	13.4±1.85 ^{bc}	12.38±1.26 ^c	1.42	0.001

Regarding the chemical traits (Table 2), The substrates significantly (P<0.05) affected the larvae’s chemical composition in terms of ash and ether extract of larvae. The highest level of (P<0.05) ether extract was obtained to larvae reared in restaurant waste than other substrates. The ash percentage was the lowest to larvae from market waste. However, the crude protein content and moisture content were not influenced by dietary treatments (P>0.05).

Discussion

In this study, market waste was more rapidly utilized by the BSF larvae compared to restaurant waste, poultry and pig droppings. The four different substrate ECD levels ranged from 8.2±1.9% to 63.2±6% with the market waste having the highest ECD (63.2±6%) and waste reduction index of 10.7±0.5%. It indicated that BSFL utilise market waste into their larval biomass better than other substrate used in this study. Restaurant waste as substrate for black soldier fly larvae (BSFL) significantly reduced ash and improved ether extract content. BSF can play a significant role in conversion of organic waste streams into biomass and bio-fertilizer, while contributing to sustainable management of the environment. These results agree with the finding of Ruslan et al (2024), reported high waste reduction ratio and larval weight when BSFL reared in cabbages and banana waste. Tabasum et al reported decreased larval growth rate when chicken manure was used as growth media for Black soldier fly larvae [8]. Veldkamp et al studied bioconversion of BSFL was produced in different organic waste, results shows that BSFL produced in swill resulted in improved waste reduction index (WRI), efficient of conversion of digested feed (ECD), and growth rate than other organic substrates [9]. This study indicated rearing of BSFL in restaurant waste resulted in high fat and ash the results show that content and resulted in lower crude protein content than other organic waste. Nayak et al. reported similar results BSFL was reared using spent mushroom. Broeckx et al indicated no significant difference in survival rate when BSFL were reared in different organic side streams [1]. Nevertheless, Holeh et al, indicated that BSFL reared in market waste mixed with hostel waste resulted in improved crude protein and calcium content, moreover found high moisture level and larval weight when black soldier fly larvae were reared in hostel waste [10]. Zandi-Sohani and Tomberlin, observed increased crude protein, and oils content when BSFL was produced in University Canteen leftover and also found decreased ash when university canteen leftover was used as growth media BSFL also indicated improved larval weight [4]. Further, reported reduced crude protein, oils, ash and dry matter when BSFL were reared in carrots pomace. Salinas et al observed decreased larval weight when swine manure used as growth substrates of BSFL [11]. Broeckx et al observed improved growth rate, feed conversion ratio, efficient of conversion of digested feed, and waste reduction (WR) when BSFL was produced in industrial food waste [1].

Conclusion

BSFL can play a significant role in conversion of organic waste streams into biomass and bio-fertilizer, while contributing to sustainable management of the environment. Valorisation of this organic waste through larval feeding activity of the black soldier fly constitutes a potential benefit, especially for developing countries. Black soldier fly larvae can be used to produce for high-quality animal feed and organic fertiliser from organic waste streams, lessen pollution. Black soldier fly larval feeding is influenced by the substrate being utilized for rearing. From the established pilot study, we can conclude that BSFL could be used to recycle organic waste in small and medium scale. It has been established that there is a possibility to process and reduce the amounts of wastes, and so it could effectively handle and reduce the organic wastes subjected to it at our facility.

Author Contributions

Conceptualization, M. Mpfu and P. Nkomboni, Methodology, M. Mpfu P. Nkomboni, T. D. Matekenya Data collection, M. Mpfu, S. Sibanda; validation, G. Sisito; Data analysis, G. Sisito and M Mpfu.; investigation, Chemical analysis, T. Rukuni and K. Ndebele.; writing—original draft preparation, M. Mpfu and P. Nkomboni; writing—review and editing, G. Sisito, S. Sibanda

All authors have read and agreed to the published version of the manuscript

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Data Availability Statement

Data are available upon request from the corresponding author and pending agreement by co-author.

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Conflicts of Interest

The authors declare that they have no competing interests

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