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BIOCONVERSION OF FOOD WASTE BY BLACK SOLDIER FLY LARVAE UNDER NATURAL SETTINGS

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ABSTRACT

The management of food waste and loss of nutrients into the environment is a pertinent problem. Sustainable livestock production under increased competition and growing cost of nutrients is a challenge faced by livestock sector. Conversion of biowaste utilising insects in the form of mini livestock is an emerging trend which offers solution for both the problems. Black soldier fly (BSF), is a naturally occurring beneficial fly and its larva convert's food and other biowaste to protein rich biomass. The present study was conducted to study the nutrient conversion efficiency of Black soldier fly larvae on food waste. It was found that under natural settings the larvae were able to achieve a bioconversion of 38-56 per cent with yield of crude protein in the range of 38 to 40 per cent. The cost of production of one unit of CP was 0.30 to 0.45 rupee in comparison to soya bean, which cost one rupee. Hence BSF could act as viable contender for soyabean as a protein source for animals.

Keywords: Black soldier fly, Food waste, Larval biomass, Crude protein

INTRODUCTION

Food is basic necessity of every living being and most life forms have a conservative approach in utilising food resources. Human beings would be the only living thing who has the liberty to waste food. The generation of food waste starts from the farmer's field and continues up to consumption. The food waste act as a focal point of origin of several other problems including stray dog menace and public health problems, due to the breeding of flies and vermin. The environmental issue due to loss of nutrients has far reaching consequences, including global warming.

The rising human population along with rising incomes have resulted in high demand for animal products, mainly from poultry sector. Soya bean is a main ingredient of poultry feed but due to high demand, alternate uses and climate change there has been a steep increase in price of the commodity. This has created interest in alternative feed sources like insects.

Human beings have always observed nature keenly to gain insights and develop solutions to problems throughout history. Waste management is one such problem which also has solutions in nature. The conversion of dead animals and plants by detrivorous and necrophagus species have always interested those who look forward for sustainable solutions. Insects play a key role in bioconversion of organic matter and have been utilised worldwide. The “mini livestock industry” is a term which has come up in this context. Flies have high fecundity and short development time which makes them suitable contender for bioconversion of waste. The utilisation of larvae of flies could become an answer to the two problems mentioned before namely managing of biowastes as well as production of an alternative protein source for the livestock sector in a sustainable manner.

MATERIALS AND METHODS

The current study was conducted at College of Veterinary and Animal Sciences, Mannuthy. Food waste from the hostels and households within the campus were collected and mixed thoroughly. Five kilogram of this mixed food waste was set in six customised bins for bioconversion by fly larvae. The bin had provisions for fly entry, larval migration and larval collection (fig 1). The study was conducted for a period of 30 days during the three seasons viz Summer (February-May), Monsoon months (June-September) and Post-monsoon months (October-January). The 30 day period started on the day bins were set and was divided into five phases of six days each (P-I to P-V). The daily weather data on temperature, was obtained from the Centre for Animal Adaptation to Environment and Climate Change Studies (CAADECCS), Mannuthy, KVASU. The number of flies was noted based on visual observations during a 15 minute observation period (Perveen and Khan 2013) at 9.00 am, 1.00 pm and 5.00 pm. The weight change of substrate and larval activity were recorded daily. The prepupae were allowed to self-harvest and were collected daily and quantified for their total biomass yield. Proximate principles of the substrate, end products and fly larvae were estimated (AOAC, 2012). The cost of one kg fresh larva was obtained by dividing the total cost of production by the total larval yield. The cost of one kg larva on dry basis was obtained by dividing the cost of one kg fresh larva by the dry matter per cent of the larva. The economic viability was assessed in comparison to soya bean (Mwaniki,2019).

RESULTS AND DISCUSSION

The maximum average daily ambient temperature (°C), during summer, monsoon and post monsoon were 35.88 ± 1.22, 31.86 ± 1.08and 32.31 ± 0.78, respectively (fig 2). In summer season the highest BSF incidence was observed in first phase(4.50± 0.48) at 5.00 pm (Table 1). In Monsoon and Post Monsoon season, the highest fly incidence was in third phase at 9.00 am (7.83 ± 0.51 and 07.83 ± 0.52 respectively). The present study was in a natural setting and the effect of climate, substrate nutrients, consistency, inter species competition, microbial population, pH, temperature, volatile emissions, previous fly population and state of decay had their role in attracting or deterring flies. The maximum temperature often exceeded 36°C in summer which could have resulted in the lower fly activity during the season. According to Chia *et al*. (2018), the ideal temperature for BSF development was between 31 to 36 °C. Fatchurochim *et al.* (1989), Tomberlin *et al.* (2002) and Lalander *et al.* (2019), have indicated that moisture content above 80 and below 60 per cent also reduced larval survival, which was also reflected in the observations. The first larval migration of BSF occurred at 413 h and was in agreement to the findings of Lalander*et al.* (2019), who reported that the first prepupa of BSF started emerging by 336 h, in fruit waste and in 672 h on vegetablewaste.

The bioconversion by fly larvae in 30 days resulted in a final residual weight that ranged from3.25 ± 0.05to 3.57 ± 0.07 g (Table 2). Kočárek (2003) had reported a biomass reduction of 50-60 per cent due to insect activity which was in accordance to our findings.

The highest biomass yield was obtained during phase IV (33.42 ± 2.77) of Summer (Table 3) which was in accordance to the studies of Chia *et al*. (2018) where favourable temperature favoured development of the larvae along with optimum moisture of substrate.

In the end of the experimental period, in comparison with the proximate in the beginning, the moisture decreased and ash increased across all seasons. The increase in crude fibre content was observed (0.91 ± 0.0 to 3.75 ± 0.17) in monsoon season (Table 4), which could be attributed to the remnant fibrous materials like banana

Table 1. BSF activity at during fixed time observations in food waste

Season	Phase	Fixed time observations		
		9.00 am	**1.00 pm**	**5.00 pm**
Summer	P-I	NIL	04.50 ± 0.42^{cC}	04.50 ± 0.48^{cD}
	P-II	NIL	01.17 ± 0.27^{bB}	01.17 ± 0.52^{bB}
	P-III	02.00 ± 0.48^{b}	00.83 ± 0.17^{abB}	00.83 ± 0.18^{abB}
	P-IV	00.67 ± 0.15^{a}	00.50 ± 0.20^{aA}	00.50 ± 0.10^{aA}
	P-V	00.33 ± 0.15^{a}	NIL	NIL
Monsoon	P-I	00.50 ± 0.39^{hHI}	01.83 ± 0.70^{hH}	02.00 ± 0.45^{iI}
	P-II	02.33 ± 0.31^{iI}	04.33 ± 0.53^{iJ}	02.50 ± 0.45^{iI}
	P-III	07.83 ± 0.52^{jI}	06.17 ± 0.48^{jJ}	04.67 ± 0.34^{jJ}
	P-IV	02.17 ± 0.35^{iI}	03.83 ± 0.36^{iJ}	02.17 ± 0.30^{iJ}
	P-V	02.50 ± 0.28^{iI}	NIL	00.17 ± 0.13^{hH}
Post Monsoon	P-I	01.17 ± 0.32^{vW}	02.17 ± 0.71^{vxVx}	02.17 ± 0.56^{wV}
	P-II	02.33 ± 0.31^{wW}	04.33 ± 0.62^{yx}	02.50 ± 0.55^{wV}
	P-III	07.83 ± 0.51^{xW}	06.17 ± 0.48^{dx}	04.67 ± 0.35^{xX}
	P-IV	01.67 ± 0.36^{vwW}	03.00 ± 0.25^{xy}	02.33 ± 0.22^{wW}
	P-V	01.00 ± 0.22^{vW}	01.0 ± 0.20^{v}	00.67 ± 0.09^{v}

Means having same superscripts (small letter a-e, h-l, v-zwithin columns, capital letters A-E, H-L, V-Z within rows doesn't differ significantly at 5 % level

Table 2. Weight (g) change in substrate during experiment period

Phase	Season		
	Summer	Monsoon	Post Monsoon
P-I	4.68 ± 0.03^{eB}	4.70 ± 0.02^{eI}	4.67 ± 0.02^{eW}
P-II	4.37 ± 0.03^{dB}	4.22 ± 0.02^{dI}	4.33 ± 0.02^{dW}
P-III	4.20 ± 0.04^{cB}	3.88 ± 0.02^{cI}	3.92 ± 0.03^{cW}
P-IV	3.95 ± 0.05^{bB}	3.63 ± 0.03^{bI}	3.50 ± 0.04^{bW}
P-V	3.57 ± 0.07^{aB}	3.27 ± 0.04^{aI}	3.25 ± 0.05^{aW}

Means having same superscripts (small letter a-e, h-l, v-zwithin columns, capital letters A-E, H-L, V-Z within rows) doesn't differ significantly at 5 % level

peels, chilly etc. which was not used by the BSF larva. The maximum decrease in NFE was observed in post monsoon (80.61 ± 0.0 to 74.57 ± 0.2). This could be attributed to the high microbial and larval activity within the substrate. Lalander *et al.* (2019), reported that the most suitable substrate for BSF larval growth is one that has a large amount of readily available carbohydrate with sufficient protein content. According to Dortman *et al.* (2017), BSF could feed on most organic matter with moisture content between 60 to 90 per cent. Our observations also showed a similar trend

The highest crude protein for BSF ranged from 36 to 38 per cent and highest

Fig. 1. Schematic diagram of experimental unit for the study

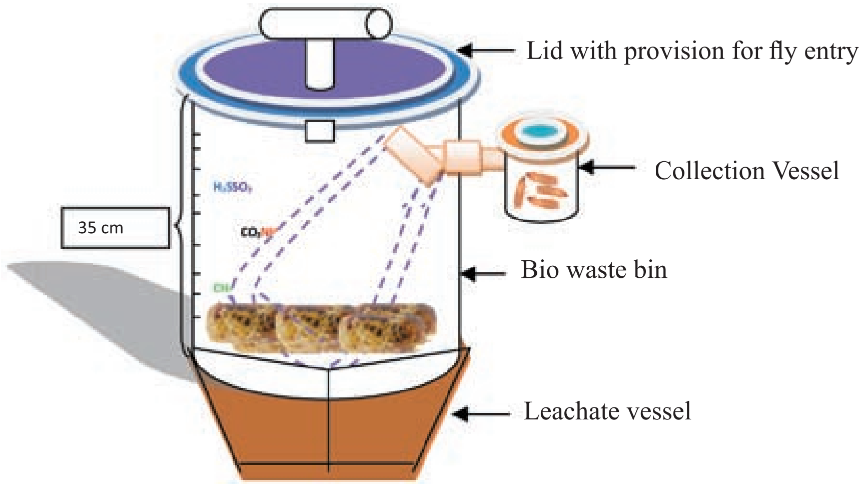
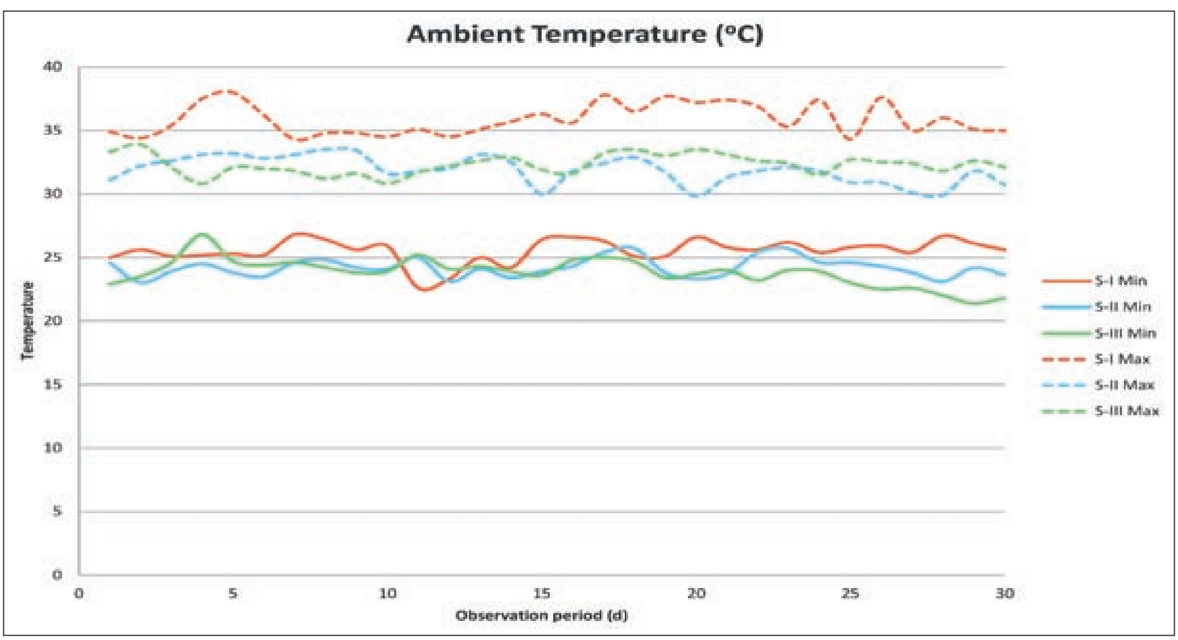


Fig. 2. Climatic parameter- Temperature, during the study period, Min- minimum temperature, Max-maximum temperature



CP was 38.88 ± 0.18 per cent in post monsoon (Table 5), which could be due to the higher crude protein content in the substrate as reported in studies of Chia *et al*. (2020), where nutrient rich substrates yielded larvae with higher crude protein. The crude protein content of BSF ranged from 34.6 to 47.7 in studies by Haasbroek (2016) which was similar to our findings.

The reduction in mass (per cent) was highest (66.2 ± 2.76 per cent) in Summer (Table 6). This corresponded to a reduction of 59 per cent on dry matter basis which was in agreement with the findings

Table 3. Larval biomass yield (g) collected in different biowastes

Phase	Season		
	Summer	Monsoon	Post Monsoon
P-I	1.08 ± 0.63^{aA}	NIL	1.15 ± 0.10^{bA}
P-II	0.21 ± 0.15^{aA}	NIL	0.53 ± 0.14^{aA}
P-III	13.52 ± 2.23^{bC}	1.23 ±0.42^{aA}	5.69 ± 1.66^{cB}
P-IV	33.42 ± 2.77^{cC}	26.54 ±1.12^{cB}	3.73 ± 0.77^{cA}
P-V	15.03 ± 3.96^{bB}	16.20 ±1.22^{bB}	6.84 ± 2.62^{cA}

Means having same superscripts doesn't differ significantly at 5 % level

Table 4. Proximate composition (%) in BW-V at the start and end of the experimental period

Season		Moisture	Total Ash	Crude Protein	Crude Fibre	Ether Extract (Crude Fat)	NFE
Summer	Start	75.24 ± 0.0^{b}	03.78 ± 0.0^{a}	11.82 ± 0.0^{a}	02.42 ± 0.0^{a}	07.86 ± 0.0^{a}	74.12 ± 0.0^{b}
	End	70.55 ± 0.2^{a}	06.04 ± 0.1^{b}	11.21 ± 0.3^{a}	04.27 ± 0.2^{b}	09.17 ± 0.1^{b}	69.31 ± 0.3^{a}
Monsoon	Start	76.37 ± 0.0^{h}	01.1 ± 0.0^{h}	12.81 ± 0.0^{i}	00.91 ± 0.0^{h}	03.37 ± 0.0^{h}	81.81 ± 0.0^{i}
	End	76.36 ± 0.3^{h}	03.94 ± 0.1^{i}	11.94 ± 0.1^{h}	03.75 ± 0.17^{i}	04.56 ± 0.3^{i}	75.81± 0.1^{h}
Post Monsoon	Start	79.54 ± 0.0^{w}	01.11 ± 0.0^{v}	12.86 ± 0.0^{w}	01.33 ± 0.0^{v}	04.09 ± 0.0^{v}	80.61 ± 0.0^{w}
	End	72.98 ± 0.2^{v}	04.19 ± 0.1^{w}	11.94 ± 0.1^{v}	04.08 ± 0.2^{w}	05.22 ± 0.2^{w}	74.57 ± 0.2^{v}

Means having same superscripts (small letter a-e, h-l, v-z within rows) doesn't differ significantly at 5 % level

Table 5. Proximate composition (%) of larva harvested during the experimental period

Season	Moisture	Total Ash	Crude Protein	Crude Fibre	Ether Extract (Crude Fat)	NFE
Summer	64.1 ± 0.1	07.85 ± 0.1	38.79 ± 0.2	7.06 ± 0.2	23.19± 0.1	23.11 ± 0.2
Monsoon	64.1 ± 0.1	09.49 ± 0.1	36.09 ± 0.1	7.56 ± 0.1	23.39 ± 0.1	23.47 ± 0.1
Post Monsoon	63.87 ± 0.1	07.96 ± 0.1	38.88 ± 0.1	7.11 ± 0.1	23.30 ± 0.1	22.75± 0.1

of Myers *et al.* (2008). Diener *et al.* (2009), reported a reduction of 65 to75 per cent and Li *et al.* (2011) reported 78 per cent reduction. Mutafela (2015) had reported a dry matter reduction of 83 per cent in fruit waste and 38 per cent for manure when treated with BSF larva. Several of the above studies were conducted under controlled lab conditions where four to five day old first instar larvae were directly deposited in the waste which helped in the higher conversions.

Food waste had highest final BSF larval yield of 445.16 ± 37.31 g in summer

Table 6. The per cent reduction in mass (kg) of different biowastes during the experimental period on dry matter basis

Season	Initial Weight (kg)	Final Weight (kg)	Reduction/Change (%)
Summer	1.238	0.498	59.8
Monsoon	1.182	0.749	36.57
Post Monsoon	1.023	0.853	16.54

Table 7. Total final biomass yield (g) and per cent conversion

Season	**Yield**	
	Gram	**per cent**
Summer	445.16 ± 37.31	8.90
Monsoon	308.6 ± 16	6.17
Post Monsoon	302.58 ± 71.95	6.05

(Table 7). The yield of larval biomass on dry matter basis was highest (8.90 per cent) during summer. Hence the conditions for the growth of BSF larvae were very congenial during summer within the waste (Chia *et al*., 2018)

The cost principles revealed that cost for producing one kg BSF larvae on fresh basis was Rs. 4.12 in summer, Rs. 5.94 in monsoon and Rs. 6.06 in post monsoon. The cost of production on crude protein basis showed that one unit crude protein of BSF larva was produced at a cost of Rs. 0.30 in summer, Rs. 0.45 in monsoon and Rs. 0.43 in post monsoon. The cost of one unit CP of soyabean is Rs 1 based on the market price at the time of the study (Das *et al.,* 2016, CASP, 2019). One unit of CP can be produced by BSF larva at a lower price than that of soya bean protein, using food waste as substrate. Hence BSF larva was found to be economically viable as an alternative to soya bean as a protein source for feeding animals.

SUMMARY

The bioconversion of food waste utilising larvae of black soldier fly under natural settings resulted in high protein biomass yield which could replace soyabean as a protein supplement in livestock feed. Higher yields were obtained during summer season which was favourable for growth of the larvae. The findings could help in managing food waste and at the same time could augment sustainable and economical animal production.

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