Effectiveness of Black Soldier Fly Larva (*Hermetia illucens*) In Refused Tea Management

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ABSTRACT

Tea is one of the major plantation crops in Sri Lanka, grown in both low and up country wet zone area. During the process of black tea production, 3-5% of refused tea is normally generated. It is generally disposed by burning or dumping. Composting has become an environmental friendly alternative where refused tea is converted into useful product but process is very slow. Black soldier fly larvae (BSFL) is economically important in recycling of organic matter while reducing house fly attack and bad odor generation. Therefore, this research was conducted with eight treatments to evaluate the potential of using BSFL in refused tea composting as an alternative approach. Temperature of decomposed materials of each of eight treatments were recorded at one week interval, compost efficiency was recorded in the final production, prepupae count and weight were recorded and nutrient analysis was conducted for produced compost from each treatment. It revealed that refused tea composting can be accelerated by introducing BSFL into refused tea mixed with fruit waste or vegetable waste successfully. Therefore, BSFL can be used as a productive species for refused tea management when combined with fast decomposable materials. However, reduction of nutrients in the process of BSFL composting is identified as a disadvantage.

KEYWORDS: Black soldier fly larvae, Composting, Refused tea

INTRODUCTION

Tea (*Camellia sinensis* L.) industry plays a major role in Sri Lankan economy. After extraction of black tea, the remained tea is discarded from factories as refused tea (3-5%) (Khan *et al.*, 2007). Refused tea can be defined as sweepings, red leafs, fluff, mature stalk, or any other product obtained in the process of manufacture of tea. Refused tea management (RTM) is a considerable challenge in tea processing industry in Sri Lanka. Most of the refused tea is burnt, dumped into landfills or used as compost. Dumping creates environmental problems, whereas burning of the waste is expensive (Khan *et al.*, 2007).

Tea leaves contain a variety of amino acids, protein, vitamins, tannins and polyphenols (Yamamoto *et al.*, 1997). Therefore green refused tea has high amount of organic matter (>90%) and nitrogen (5-7%) that could be used as composting materials to restore the soil fertility (Khan *et al.*, 2007). Carbon nitrogen ration (C: N ratio) of refused tea is comparatively high and it is about 31:1 (Abdulghani, 2012). Even though there is a possibility of producing compost from refused tea, it is not normally practiced due to slow decomposing nature.

Compost is one of a common organic fertilizers used all over the world and it is the product of a controlled aerobic decomposition of organic matter. It is a stable, dark brown, soil-like material, containing important plant nutrients as nitrogen, potassium and phosphorus (Rouse *et al.*, 2008). The fastest way to produce fertile, sweet-smelling compost is to maintain a C: N ratio somewhere around 25 to 30 parts carbon to 1 part nitrogen, or 25-30:1 (Anon, 2014). Acceleration of the composting process can be accomplished by blending high C: N ratio materials with low C: N ratio materials.

There are several technologies to produce compost such as vermicomposting, hugelkultur (raised garden beds or mounds), black soldier fly larvae composting, cockroach composting, bokashi, compost tea *etc.* It is an environmental friendly way of minimizing solid waste generation. It helps to avoid landfilling, reduces greenhouse gas emissions, decrease soil erosion and increase soil carbon storage.

Black soldier fly (*Hermetia illucens*), belongs to family Stratiomyidae can be used to convert organic waste into compost. *Hermetia illucens* completes life cycle with four stages. The female black soldier fly has a life span of 5-8 days and deposits a mass of about 500 eggs in decaying matter. Black soldier fly relies solely on its body fat reserve. Adult is not being regarded as a vector of diseases (Silva *et al.*, 2015). Larvae of the BSF are involved with cycling on a wide range of rotting fruits, vegetables, fish offal, human excreta and animal manure. In ideal conditions, larvae become mature in two months. The duration of the pupal stage is about 14 days. Once hatched, larvae start to feed on waste, thus achieving a dry mass volume waste reduction of 55% (Myers *et al.*, 2008). An additional advantage of *Hermetia illucens* is its capacity to repel oviposition of female house flies (*Muscado mestica)* (Bradley and Sheppard, 1984). Black solder fly larva are vastly used to reduce manure accumulation and harvested prepupae can be used as an animal feed (Myers *et al.*, 2008; Newton *et al.*, 1995; Sheppard, 1983). Larval activity reduces bacterial growth not only the dry mass but also several nutrient contents such as nitrogen or phosphorus. Under ideal conditions with abundant food sources larvae can mature in two weeks. But, food shortage and low temperatures can extend the larval period up to four months (Furman, *et al.*, 1959). Due to high larval densities of BSFL and the voracious appetite of the larvae, decomposition of fresh material become fast and suppressed bacterial growth, thereby reduces the bad odor.

Therefore, this experiment was carried out to investigate the possibility of using BSFL in refused tea management. Different types of organic wastes mixed with refused tea at different levels were subjected to composting by introducing BSFL to evaluate effectiveness of BSFL in refused tea composting under natural conditions.

MATERIALS AND METHODS

Experimental Site

This study was carried out at the Regional Agriculture Research and Development Centre, Makandura (NWP), from January to May 2016. The monthly mean temperature at Makandura during the experimental period was 32.7 °C while the monthly mean relative humidity and rainfall were 80.68% and 8.49 mm respectively. Black soldier fly larvae were collected from compost bins located in Makandura and Kuliyapitiya areas. Further they were multiplied in compost bins at Makandura research station.

Experimental Design

The treatments were arranged in a Complete Randomized Design (CRD) with three replicates. Twenty four plastic containers (volume of 100 L) were prepared by drilling drainage holes at the bottom.

Refused tea (RT) from tea factories, kitchen waste (KW) from cafeteria of Wayamba University, vegetable waste (VW) and fruit waste (FW) disposed from daily fair were used as materials for treatments. Substrates collected from *Pilisaru* compost producing center (PW) at Makandura were used as solid waste. *Gliricidia sepium* collected from the Regional Agriculture Research and Development Centre at Makandura were used as a green manure (GM) for treatments.

Table 1. Tested combination of materials for composting

Treatment	Composition (kg)
T_1	40 RT
T_2	10 RT+10 KW+10 VW+10 GM+300 BSFL
T_3	10 RT+10 KW+10 FW+10 GM+300 BSFL
T_4	10 RT+20 PW+10 GM+300 BSFL
T_5	20 RT+10 KW+10 GM+300 BSFL
T_6	20 RT+10 KW+10 FW+300 BSFL
T_7	20 RT+10 KW+10 VW+300 BSFL
T_8	20 RT+20 PW+300 BSFL

RT- Refused tea, KW- Kitchen waste, VW- Vegetable waste FW- Fruit waste PW- Pilisaru waste, GM- Green manure, BSFL-Black soldier fly larva

Data Recording

Temperature inside compost bins were measured by soil thermometer at weekly intervals and mean daily air temperature was also recorded. Number of days required to complete composting and the weight of 1 kg of sieved compost which was sieved by 4 mm size mesh was recorded to determine the compost production efficiency.

Compost Nutrient Analysis

Nutrient analysis was conducted to determine quality of compost produced by each treatment.

Organic carbon was estimated according to Walky-black method. Total nitrogen was measured by Kjeldahl method. Available phosphorus was estimated by acid base method using spectrophotometer. Available potassium was estimated by acid base method using flame photometer. pH was measured by 1:5 (water solution method) after calibrating the instrument at pH 4 and pH 7. Electric conductivity was measured by 1:5 (water solution method).

Statistical Analysis

The data were statically analyzed by (SAS) Statistical Analysis System (version 9.2).

RESULTS AND DISCUSSION

Temperature Changes with Time

Among eight treatments, the highest temperature was recorded in T_3 and T_6 (42-43 °C) because T_3 and T_6 contain fruit waste. Black soldier fly larva most prefer fruit waste. High metabolic activity of BSFL in fruit waste leads to increasing of temperature inside the compost bin. The lowest temperature was recorded in T_1, T_4 and T_8 (26 °C) due to low metabolic activity of BSFL in high amount of cellulose. That can be the reason for low temperature value. Though graph is similar to the normal composting graph, the temperature was not higher than 55 °C. Therefore, pathogens can't be destroyed at that temperature. But according to the Erickson *et al.* (2004) pathogens can be destroyed by the activity of BSFL (Figure 1).

Compost Production Efficiency

All seven treatments were recorded with higher compost production efficiency with compared to the control T_1 (Table 2). Among treatments the highest composting efficiency was recorded in T_3 (42.933). It may be due to high amount of readily decomposable materials in fruit waste. Vegetable waste also more favorable to BSFL in T_2 due to high amount of carbohydrates and fleshy nature. The lowest value was recorded in T_4 (12.767) due to high amount of cellulose in *pilisaru* waste.

Table 2. Efficiency of compost production

Treatment	Composting efficiency (%)[1]
T_1	07.682[f]
T_2	35.933[a]
T_3	42.933[a]
T_4	12.767[e]
T_5	33.800[c]
T_6	38.567[b]
T_7	26.167[d]
T_8	25.000[d]

[1]*Composting efficiency after sieved by 4 mm mesh; Treatments- refer Table 1*

Prepupae Count

Highest prepupae count was observed in T_2 (796) throughout the three months period which is significantly higher compared to other treatments. This may be due to high amount of fleshy materials (vegetable waste, green manure) in this treatment. It was noted that fleshy materials remained in the treatment bin more than one month causes higher prepupae count throughout the composting period. According to James (1935) vegetable waste is more favorable to BSFL. In T_3 highest prepupae count was recorded within first week. It may be due to their preference and high consumption of fruit waste in the bin. As a result of high consumption rate of fruit waste, amount of fruit waste was significantly reduced within short period of time and gradually reduction of prepupae count could be observed. The lowest prepupae count (23) was observed in T_4 and T_8 probably due to high amount of matured leaves in *pilisaru* (Figure 2). Low nutrient and the high cellulose content in the bin may be the reason for reduction of prepupae in T_4 and T_8.

According to the results T_5, T_6, and T_7 had the lowest prepupae count due to high amount of refused tea (20 kg of refused tea in the bin) than T_2, T_3 and T_4 (10 kg of refused tea in the bin).

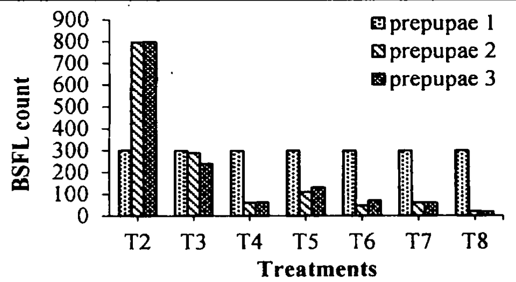

Figure 2. Black soldier fly larvae (BSFL) count with time *Prepupae 1- prepupae in start, Prepupae 2- prepupae in 45 days, Prepupae 3- prepupae in 90 days, Treatments- refer Table 1*

Nutrient Analysis of Compost

Recommendation for nutrients of compost is about 1% of nitrogen (N), 0.5% of phosphorous (P) and 1% of potassium (K), 20% of organic carbon (Standard in Sri Lanka Standards Institution (SLS 1246:2003).

Organic Carbon

No significant difference among T_1, T_4 and T_8 was observed. It may be due to high cellulose content of the materials in the bins under slow decomposing process.

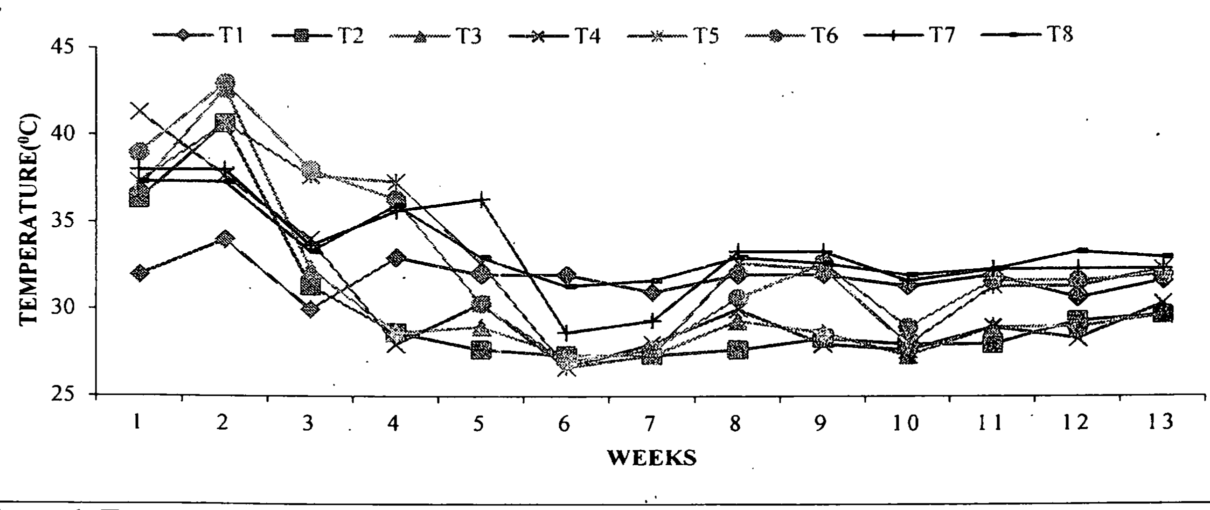

Figure 1. Temperature changes with time. *Treatments- refer Table 1*

Within first month T_2, T_3 and T_6 had the SLS recommended for organic carbon (Table 3). With the time, percentage of organic carbon was reduced due to decomposition of materials (Table 4).

Total Nitrogen

With compared to the first month and third month the nitrogen level become reduced in all other treatments except the control (T1). According to the recommendation, within the first month proper nutrient value can be obtained (Table 3). Low value of nitrogen is a disadvantage of compost produced by BSFL due to reduction of nitrogen. This could be overcome by adding *Gliricidia sepium* and sunhemp (*Crotalaria juncea*) which are proved to enrich the nitrogen level of the mixture.

Available Phosphorus

The highest phosphorus value was recorded in T_7 during first month and third month (Table 3 and Table 4). Phosphorus value in BSFL composting was lower than traditional composting because BSFL are able to reduce available phosphorus by 61–70% across treatments according to *Myers et al.* (2008). It is a disadvantage in BSFL compost production.

Available Potassium

There was a significant difference among treatments. But, the potassium percentage becomes reduced in all treatments in first month and third month (Table 3 and Table 4).This finding is consistent with published data where Potassium value was reduced by 52% according to *Myers et al.* (2008).

pH

In all treatments pH become increased with respect to the control in both first and third month (Table 3 and 4). As BSFL is capable of reducing acidity, they can be effectively used for compost production with acidic substrates like refused tea.

Electric Conductivity (EC)

The highest EC value was recorded in first and third month in T_3 (Table 3 and Table 4) due to the use of BSFL. High EC value of compost increases the ion exchange of plants.

It is suggested that, if BSFL compost bins are modified to retain the prepupae within the bin, nutrient reduction of compost can be minimized. As prepupal black soldier flies composed of 44% dry matter, 42% protein and 35% fat, including essential amino and fatty acids (Hale *et al.*, 1973).

Table 3. Nutrient analysis of compost within one month

Treatment	pH	EC (ms/cm)	N (%)	P_2O_5 (%)	K_2O (%)	Organic carbon (%)
T_1	4.95^d	4.25^{cd}	3.56^a	0.41^b	0.86^a	64.60^b
T_2	6.92^a	7.28^b	1.38^b	0.16^c	0.55^{bc}	32.69^c
T_3	6.46^{bc}	13.45^a	1.44^b	0.19^c	0.38^d	22.37^a
T_4	6.47^{bc}	2.23^d	1.26^{bc}	0.43^b	0.42^{cd}	63.47^b
T_5	6.36^{bc}	5.53^{bc}	1.43^b	0.11^c	0.56^b	54.72^c
T_6	6.16^c	7.31^{bc}	1.26^{bc}	0.66^a	0.52^{bc}	25.84^a
T_7	6.20^c	6.58^b	1.09^c	0.67^a	0.57^b	54.01^d
T8	6.74^{ab}	2.53^d	0.76^d	0.40^b	0.83^a	62.75^b
LSD	0.39	2.08	0.22	0.11	0.12	3.15

Means followed by the same letters in each column are not significantly different at 0.05 levels. All values are based on dry weight basis. EC- Electric conductivity, N%- Total nitrogen percentage, P_2O_5%- Available phosphorus percentage, K_2O%- Available potassium percentage; T1- 40 (Control) RT, T2- 10 RT+10 KW+10 VW+10 GM+300 BSFL, T3- 10 RT+10 KW+10 FW+10 GM+300 BSFL, T4- 10 RT+20 PW+10 GM+300 BSFL, T5- 20 RT+10 KW+10 GM+300 BSFL,T6- 20 RT+10 KW+10 FW+300 BSFL, T7- 20 RT+10 KW+10 VW+300 BSFL, T8- 20 RT+20 PW+300 BSFL

Table 4. Nutrient analysis of compost within three month

Treatment	pH	EC (ms/cm)	N (%)	P_2O_5 (%)	K_2O (%)	Organic carbon (%)
T_1	4.79^c	5.66^d	2.49^a	0.34^c	0.81^a	27.58^a
T_2	6.71^a	7.26^b	0.57^{bcd}	0.13^e	0.45^c	10.75^d
T_3	6.08^c	9.05^a	0.52^{cd}	0.13^e	0.32^f	12.55^{bcd}
T_4	5.77^d	5.08^c	0.71^{bc}	0.31^c	0.33^f	13.77^{bcd}
T_5	5.80^d	6.49^c	0.67^{bc}	0.04^f	0.46^c	14.96^b
T_6	6.93^a	7.49^b	0.38^d	0.42^b	0.37^e	14.05^{bc}
T_7	5.79^d	7.04^b	0.17^e	0.52^a	0.42^d	13.12^{bcd}
T_8	6.41^b	4.58^c	0.76^b	0.22^d	0.57^b	11.21^{cd}
LSD	0.22	0.52	0.20	0.07	0.03	4.20

Means followed by the same letters in each column are not significantly different at 0.05 levels. All values are based on dry weight basis. EC-Electric Conductivity, N%- Total nitrogen percentage, P_2O_5%- Available phosphorus percentage, K_2O%- Available potassium percentage

CONCLUSIONS

Results revealed that refused tea composting can be accelerated by introducing BSFL into refused tea mixed with fruit waste or vegetable waste successfully. Reduction of nutrients in the process of BSFL composting is identified as a disadvantage. Further studies are necessary, to investigate the possible relationships between different stages of BSFL life cycle and decomposing ability according to the ingredients use for composting. It was also concluded that the recipes having 25% refused tea can be recommended for BSFL composting when waste fruit and vegetable waste is used. However further investigation is necessary to determine the appropriate combination of materials, optimum percentage of refused tea and BSFL count.

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REFERENCES

Abdulghani, E.T. (2012). Effect of black refused teas on some of soil properties and barley (*Hordium vulgar L.*) Tikrit University for Agricultural Science. **12**, 186-189.

Anon. (2014). Composting process and techniques. Food and Agriculture Organization corporate Document repository. Available from: http://www.fao.org/docrep/007/y5104e/y5104e05.html.(Accessed 17 April 2016).

Bradley, S.W. and Sheppard, D.C. (1984). Housefly oviposition inhibition by larvae of *Hermetia illucens*, the black soldier fly. *Journal of Chemical Ecology*, **10**, 853-859.

Erickson, M.C., Islam, M., Sheppard, C., Liao, J. and Doyle, M. P. (2004). Reduction of *Escherichia coli* and *Salmonella enterica* in chicken manure by larvae of the black soldier fly. *Journal of Food Protection,* **67**, 685-690.

Furman, D.P., Young, R.D. and Catts, E.P. (1959). *Hermetia illucens* (L) as a factor in the natural control of *Muscado mestica* (L). *Journal of Economic Entomology,* **52**, 917–21.

Hale, O.M. (1973). Dried *Hermetia illucens* larvae (Diptera: Stratiomyidae) as feed additive for poultry. *Journal of the Georgia Entomological Society,* **8**, 16–20.

James, M.T. (1935). The genus Hermetia in the United States (Diptera: Stratiomyidae). *Bulletin of the Brooklyn Entomological Society,* **30**, 165–170.

Khan, M.A.I., Ueno, K., Horimoto, S., Komai, F., Tanaka, K. and Ono, Y. (2007). Evaluation of the physio-chemical and microbial properties of green refused tea-rice bran compost and the effect of the compost on spinach production. *Plant production Science,* **10** (4), 391-399.

Myers, H.M., Tomberlin, J.K., Lambert, B.D. and Kattes, D. (2008). Development of black soldier fly (Diptera: Stratiomyidae) larvae fed dairy manure. *Environmental Entomology*, **37**, 11-15.

Newton, G.L., Sheppard, D.C., Thompson, S.A. and Savage, S. (1995). Soldier fly benefits: house fly control, manure volume reduction and manure nutrient recycling. *Journal of Animal and Dairy Science*, **8**, 275-325.

Newton, G.L., Booram, C.V., Barker, R.W. and Hale, O.M. (1977). Dried *Hermetia illucens* larvae meal as a supplement for swine. *Journal of Animal Science*, **44**, 395-400.

Rouse, J., Rothenberger, S. and Zurbrugg, C. (2008). *Marketing Compost: A guide for Compost Producers in Low and Middle-Income Countries.* Switzerland.

Sheppard, D.C. (1983). Housefly and lesser fly control utilizing the black soldier fly in manure management-systems for caged laying hens. *Journal of Environmental Entomology*, **12**, 1439-1442.

Silva, G.D.R., Dissanayake, D.M.P.S. and Weerakkody, W.J.S.K. (2015). Effectiveness of Black Soldier Fly Larva in Solid Waste Management and Composting. In: Proceedings of 14th Agricultural Research Symposium, 219–223.

Yamamoto, T., Juneja, L.R., Chu, D.C. and Kim, M. (1997). *Chemistry and applications of green tea,* CRC press. Florida, USA.