DOI 10.55278/QFAB1574

Treasure out of trash - black soldier fly

Pushpalatha, M. [1]*, Ankush Subhash Gadge[2], Devanand Rajaram Bankar[3]
[1, 3]*Mahatma Phule Krishi Vidyapeeth, Rahuri- 413722, Maharashtra, India*
[2]*Directorate of Onion and Garlic Research, Rajgurunagar, Pune- 410505, Maharashtra, India*
****Corresponding author: pushpalatham143@gmail.com***

Abstract

The Black Soldier Fly (*Hermetia illucens* (Linn.)) is a cosmopolitan tropical fly belonging to the Stratiomyidae family (Order: Diptera) having great economic benefits and environmental potential impact for the processing of various organic waste and by-products into insect-based products. It has a very short life cycle of 40-50 days and a high reproductive potential (nearly 500 eggs/ female). *Hermetia illucens* is the best possible insect species since it can eat and digest a variety of solid organic waste materials. The mature larvae contain fat content of about 20% - 40%. Thus, the black soldier fly larvae can be exploited as the better waste decomposer, protein and lipid feedstock for poultry feed and also for biodiesel production.

Introduction:

The Black Soldier Fly, *Hermetia illucens* (Linn.) (Diptera: Stratiomyidae) is a cosmopolitan tropical fly which is having great economic benefit and environmental potential impact for the processing of various organic waste and by-products into insect-based products. It is a relatively large fly with wasp-like appearance. However, unlike wasps, *H. illucens* have only one pair of wings and lack a sting. Mexico is believed to be the native of black soldier fly with its distribution all over the world (Hauser *et al.*, 2015). *Hermetia illucens* is usually found in outdoor environments near livestock or decaying organic matter, including animal waste. The larvae of Black Soldier Fly (BSF) can consume various types of biodegradable materials including food waste, animal manure (pig manure, poultry waste) and much other indigestible organic waste. Therefore, larvae are widely used in manure management and the conversion of organic waste into useful products such as compost (Newton, 2005). The BSF larvae can reduce the accumulation of organic waste by up to 50% in a very short time which makes it ideal for optimal reduction of environmental pollution while the biomass is produced. By this process it can be used as a source of protein for animal feed, fatty acids for biofuel, minerals, chitin and chitosan for production of various types of bio-based products.

Life cycle

Mating occurs two days after adult emergence from the pupal case. Upon successful mating the female begins with the egg laying.

(a) Eggs: The female deposits around 500 eggs in a single clutch in decaying matter such as dung, carrion, garbage and other organic waste or in cracks and crevices. Incubation period of the eggs are four days. Each egg is oval in shape, pale yellow or creamy white in colour and measures about 1 mm in length (NCIPMI 1998).

(b) Larva: After the incubation period of 4 days, the neonates emerge. The early instar larvae are dull, whitish in colour with a small projecting head, having biting and chewing mouthparts. The larvae can attain a length of 27 mm and a width of 6 mm at their last instar. The insect totally has six instars and require approximately 14-20 days for complete larval development (Hall and Gerhardt 2002). Black soldier fly larvae are insatiable feeders during their larval development, Adults rely on the fats stored from the larval stage and do not feed (Newton *et al*., 2005).

(c) Pupa: Before pupation, the fifth instar larva migrates from the feeding site to dry sheltered areas such as ground vegetation to initiate pupation. The exoskeleton (skin) darkens, and a pupa develops within. Pupation will be completed in about two weeks (Hall and Gerhardt, 2002).

(d) Adults: Adults are black or blue in colour and have a wasp-like appearance. Soldier flies also have two translucent "windows" located on the first abdominal segment. Adults range from 15 to 20 mm in length. (Sheppard *et al*., 2002). The adults have elongated three segmented antennae and white colorations near the end of each leg. The emerged adults will live for 4-6 days and the total life cycle will be completed within 40-50 days.

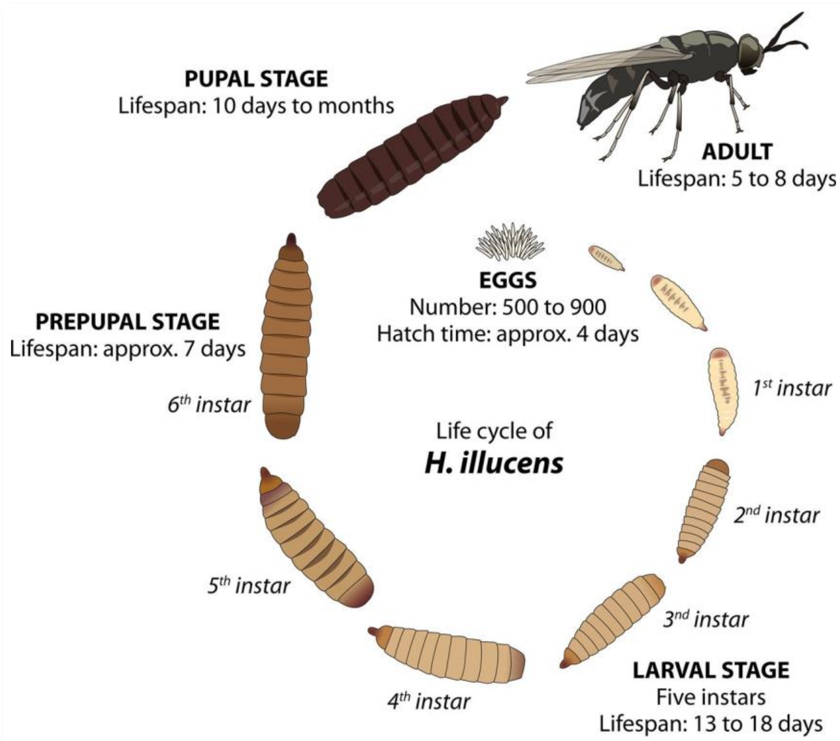

Fig. 1 Life cycle of Black Soldier Fly, *Hermetia illucens* (Linn.)

(Photo courtesy: De Smet *et al*., 2018)

Rearing and breeding under indoor conditions:

Indoor rearing facilities usually consist of cage layered houses under the animal producing waste. Optimum temperature, light intensity and humidity ranges are to be maintained to ensure high yield of *H. illucens* larvae. Temperature of 29–31°C with 50–70% RH is most suitable for larval development. Rearing facilities operate by self-collection of *H. illucens* pre-pupae as they migrate away from their habitat into collection bins or ramp for pupation.

Thus, the collected pupae are then brought into a greenhouse where they will hatch into adults. The size of screen cages for effective rearing of *H. illucens* adults vary. The space required for aerial mating is very large which the rearers can't afford. But 2×2×4m caged house is proved to be good for successful mating of BSF (Sheppard *et al*., 2002). As sunlight and intensity of sunlight influence the mating, it is recommended to keep adult *H. illucens* exposed to sunlight or in artificial light. 24–40°C of temperature, 30-90% of RH and over 200 µmolm^{2}s^{-1} of optimal light intensity are ideal for mating and oviposition. A moist container or corrugated cardboard tray (*i. e*., egg-holding tray) should be provided and placed near decaying organic matter which attracts gravid females for successful oviposition.

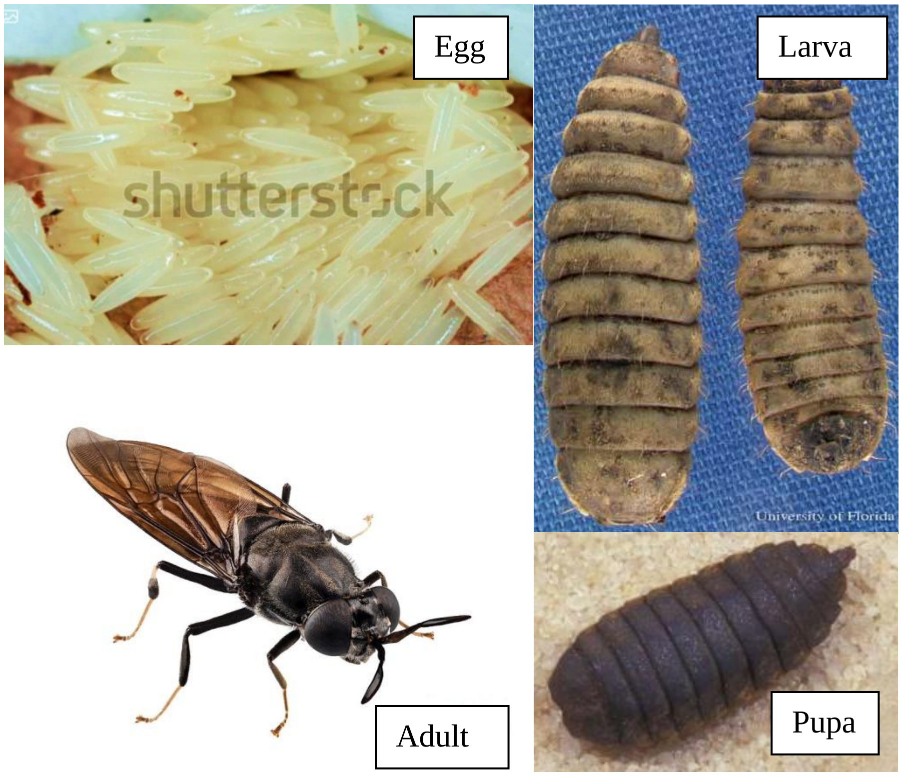

Fig. 2 Different life stages of *Hermetia illucens* (Linn.)

(Photo courtesy: James Castner, University of Florida and Shutterstock)

Blackfly in treatment of organic waste

Food waste is the prime source of organic wastes. Nearly, one-third of food generated is being wasted all over the globe (nearly 1.3 billion tons/year) without consumption (FAO, 2020). Keeping food waste apart, there is one more solid organic waste material *i. e.*, sewage sludge. It is obtained as a by-product from biological wastewater treatment plants. Approximately 2010 million MT of municipal solid wastes is being generated per year across the globe and by 2050 it is presumed to reach 3400 million MT per year (Ellis, 2018). Animal waste manure from farm is another solid organic waste material that is increasing in terms of capacity. Consequentially, 65% of N_2O, 64% of NH_3 and 10% of greenhouse gases are discharged globally because of the various agricultural activities, primarily via production of animal manure (Gómez-Brandón *et al*., 2013).

The conventional mishandling of organic wastes is contributing to a wide range of environmental hazards and economic misery (Ferronato and Torretta, 2019). Therefore, proper groundwork for waste disposal is required to cast out the huge amount of waste in a safe and sustainable manner with limited or no discharge of greenhouse gases. In this view, *H. illucens* is a perfect insect species as it can feed and breed on a variety of solid organic waste materials. Leaving apart the role in decomposition, the mature larva contains about 20% - 40% of fat. Therefore, the larval biomass can be used as lipid and even as a protein feedstock in the production of biodiesel and as poultry feed respectively (Oonincx *et al*., 2015). Furthermore, the adults of BSF have the ability to control houseflies that can affect human and animal health by preventing them from oviposition. Moreover, adults are not pests and the larvae are saprophagous which are capable to feed on various and large amounts of solid organic wastes (Čičková *et al*., 2015).

Fig. 3 Larvae of Black soldier fly engaged in decomposition of manure
(Photo courtesy: Lyle J. Buss, University of Florida)

Feeding substrates for BSF larvae

Single substrate

Feeding substrates of the larvae are particularly carbohydrates and protein contents which remarkably affect the larval growth, its bioconversion efficiencies, pre-pupal weights and the nutritional contents of the mature larvae (on a dry weight basis) (Kinasih *et al*., 2018). Among all the single substrates, chicken manure feed achieved the shortest larval development time followed by animal manure, waste from the restaurant and vegetable and fruit residue (Spranghers *et al*., 2017). Increased total larval biomass is directly correlated with chicken manure feed. The sludge from secondary waste water can also be used as a single substrate. But it lengthens the development time of the pre-pupa to emerge and the emerged pre-pupa will be smaller compared to other feeds. To overcome this drawback, the employment of undigested sludge is suggested.

Blended substrate

The common organic wastes administered for the nurturing of larvae of black soldier fly are waste coconut endosperm, dairy manure and sludge as these wastes have been produced in vast amounts as an outcome of various agricultural and industrial activities. The valorization of wastes by the sole utilization of the BSF larvae is very slow and not promising as the dairy manure comprised of hemicellulose, cellulose and lignin which makes it difficult for the BSFL to digest even though the manure has a good buffering ability (Mata-Alvarez *et al*., 2014). Therefore, there is a need of blending dairy manure with SCR for larval co-digestion as dairy manure is generally high in water insoluble nutrients *i.e.*, proteins and fats. Waste coconut endosperm is also blended with SCR at 3:2 ratio which helps the larvae to gain the highest weight (twice the mass of the larvae fed with only coconut endosperm waste). Reduced growth weight of the larvae due to the insufficient nutrients in sewage sludge is the main drawback which in turn leads to a small attainable larvae and a short period of pupation. Therefore, chicken manure or wheat bran is recommended for mixing with sludge to obtain maximum larval yield.

Microbial fermented substrate

In order to increase the nutritional composition of the feeding substrates of larvae prior to their administrations, the microbial modification method is employed by accomplishing fermentation in waste biomass. However, the occurrence of mazy organic waste materials such as lignocelluloses from plant-based products in larval feed is generally hard to ingest and digest since the larvae need to engulf the epidermis layer of the plants prior to ingesting. Thus, fermentation via microbes is viewed as a necessary work to bring down the complex ingredients via hydrolysis into simple molecules (Wong *et al*., 2020).

Various kinds of microorganisms are employed in the process and the fermentation thus, is categorized into two types based on the inoculation modes:

a) In-situ fermentation:

When the micro-organisms are inoculated to execute the fermentation process simultaneously with the valorization of waste organic substrates by the black soldier fly larvae it is referred as in-situ fermentation. *Saccharomyces cerveciaea*, *Bacillus subtilis*, *Lactobacillus buchneri* are employed in in-situ fermentation (Wong *et al*., 2020).

b) Ex-situ fermentation

The fermentation is referred to as ex-situ when the waste organic substrates are fermented by the microorganisms prior to feeding by the black soldier fly larvae. In this case, fermentation is an ongoing process throughout the larval feeding period. *Saccharomyces cerevisiae* for rice straw at 37 °C for 48 hours, *Aspergillus oryzae* for fermented maize straw, waste coconut endosperm fermented by mixed-bacterial powder (Reckitt Benckiser, UPN:1920080310) for 28 days prior to feeding the BSF larvae are some of the examples of Ex-situ fermentation (Mohd-Noor *et al*., 2017).

Future prospects

Valid and sound figures on environmental requirements of black soldier fly and the complete biological processes of the treatment is need to be provided in order to increase the performance which contributes in increasing the financial output is one of the significant prospects in future. This will empower the flexibility of the waste management plan along with the treatment plant in which the black soldier fly unit is established. This research needs to take an account on the effects of up-scaling and finally coming up with a refinement of design and operation for the facility for optimized profit. Such kind of research needs to occur constantly, involving researchers, plant operators and regional planners with closely bound information exchange networks. This is to make sure that there are immediate responses to emerging new developments and challenges.

Conclusion

Hermetia illucens with its high reproductive capacity and short life cycle has a great waste management potential as it can add value to various organic wastes and transform into its biomass. It can recycle waste into clean energy and reduce environmental pollution of the manure. It is an exceptionally resistant species and has a capacity to deal with demanding and changing environment such as oxygen deficiency, drought, food shortage etc. With respect to their robustness, survival of the species as a whole will not be endangered within a region. But increased heavy metal concentrations, temperatures reaching lethal values or a waste source turning anaerobic, exceeding a certain threshold level may prove detrimental to the larval population. The small sized larval harvest is usually associated with unavailability of essential nutrients in the food substrates. Hence, mixing with other substrates and fermentation by microbes has been suggested to hasten the nutritional values of larval feeding substrates. Overall, BSF larva is a good example for ‘Treasure Out of Trash’.

References

Anonymous. 1998. Insect and related pests of man and animals. *North Carolina Integrated Pest Management Information*, NCIPMI. http://ipm.ncsu.edu/AG369/notes/ black_soldier_fly.html (14 July 2009).

Anonymous, 2020, Food loss and waste database, Food and Agriculture Organization.

Buss, L. J., 2018, Featured creatures, Entomology and Nematology, Florida Department of Agriculture and Consumer Services, University of Florida.

Castner, J., 2018, Entomology and Nematology, Florida Department of Agriculture and Consumer Services, University of Florida.

Čičková, H., Newton, G.L., Lacy, R.C. and Kozánek, M. 2015. The use of fly larvae for organic waste treatment. *Waste Manage*., **35**: 68-80.

De Smet, J., Wynants, E., Cos, P., Campenhout, L. V., 2018, Microbial community dynamics during rearing of black soldier fly larvae (*Hermetia illucens*) and Impact on Exploitation Potential. *Appl. Env. Micrbiol*., **84**(9): 1-17.

Ellis, C. 2018. World Bank: Global waste generation could increase 70% by 2050. Available online. https://www.wastedive.com/news/wor ld-bank-global-waste generation2050/533031/.

Ferronato, N. and Torretta, V. 2019. Waste mismanagement in developing countries: A review of global issues. *Int. J. Environ. Res. Public Health*., **16**: 1060

Gómez-Brandón, M., Juárez, M. F. D., Domínguez, J. and Insam, H. 2013. Animal manures: Recycling and management technologies. *Biomass Now-Cultivation and Utilization; InTech: Rijeka, Croatia,* 237-272.

Hall, D. C. and Gerhardt, R. R. 2002 Flies (Diptera). In: Medical and Veterinary Entomology. Academic Press. San Diego, California, 127-161.

Hauser, Martin and Marshall. W. 2015. The historical spread of the Black Soldier Fly, *Hermetia illucens* (L.) (Diptera, Stratiomyidae, Hermetiinae) and its establishment in Canada*. J. Kansas Entomol. Soc*., 51-54.

Kinasih, I., Putra, R. E., Permana, A. D., Gusmara, F. F., Nurhadi, M. Y. and Anitasari, R. A. 2018. Growth performance of black soldier fly larvae (*Hermetia illucens*) fed on some plant based organic wastes. *Hayati*, **25**: 79.

Mata-Alvarez, J., Dosta, J., Romero-Güiza, M., Fonoll, X., Peces, M., Astals, S. 2014. A critical review on anaerobic co-digestion achievements between 2010 and 2013. *Renew. Sust. Energ. Rev*., **36**: 412-427

Mohd-Noor, S. N., Wong, C. Y., Lim, J. W., Uemura, Y., Lam, M. K., Ramli, A., Bashir, M. J. and Tham, L. 2017. Optimization of self-fermented period of waste coconut endosperm destined to feed black soldier fly larvae in enhancing the lipid and protein yields. *Renew. Energ.,* **111**: 646-654.

Newton, L., Sheppard, C., Watson, D. W., Burtle, G. and Dove, R. 2005. Using the black soldier fly, *Hermetia illucens*, as a value-added tool for the management of swine manure. *Waste Management Programs*. North Carolina State University.

Oonincx, D., Van Huis, A., Van Loon, J. 2015. Nutrient utilisation by black soldier flies fed with chicken, pig or cow manure. *J. Insects as Food Feed*, **1:** 131-139.

Sheppard, D. C., Tomberlin, J. K., Joyce, J. A., Kiser, B. C. and Sumner, S. M. 2002. Rearing methods for the black soldier fly (Diptera: Stratiomyidae). *J. Medical Entomol.,* **39**: 695-698.

Spranghers, T., Ottoboni, M., Klootwijk, C., Ovyn, A., Deboosere, S., De Meulenaer, B., Michiels, J., Eeckhout, M., De Clercq, P. and De Smet, S. 2017. Nutritional composition of black soldier fly (*Hermetia illucens*) prepupae reared on different organic waste substrates. *J. Sci. Food Agric*., **97**: 2594-2600.

Tomberlin, J. K., Sheppard, D. C. 2001. Lekking behaviour of the black soldier fly (Diptera: Stratiomyidae). *Florida Entomologist*, **84**: 729-730.

Wong, C. Y., Mohd Aris, M. N., Daud, H., Lam, M. K., Yong, C. S., Abu Hasan, H., Chong, S., Show, P.L., Hajoeningtijas, O.D. and Ho, Y. C. 2020. In-situ yeast fermentation to enhance bioconversion of coconut endosperm waste into larval biomass of *Hermetia illucens*: Statistical augmentation of larval lipid content. *Sustainability*, **12**: 1558.

MS Received 11 December 2022
MS Accepted 13 March 2023