



Black Soldier Fly/Larvae: A Weapon for Solid Waste Management and Alternative Feed for Poultry and Aquatic Industries

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Abstract: In developing countries like India, the most unresolved threats present at our urban citizens are related to solid waste management. Even though various methods were practiced previously, due to various scenarios the degradation and disposal of waste has yet remained as a challenge. Thus, to overcome the present situation, Black Soldier fly/larvae (BSF/L) based waste disposal and management can be implemented as one of the main practices as it has been proved to degrade kitchen solid waste to organic waste within a few hours. These larvae after feeding on solid wastes like vegetable waste, agricultural waste and bio-waste mature into a complete fly after several stages of development. Simultaneously, late larval stage i.e. the pre-pupa can be also used as feed in poultry and fish industries. It has been reported that the BSFL can consume organic waste in larger quantities and the rate of degradation is estimated to be higher than any other species of their kind. Moreover, as the rate of reproduction of BSF is very high and provides maximum yield it makes waste management very productive and profitable with greater outcomes. The larvae of BSF used as poultry and fish feed consist of 70% of protein and other of carbohydrates, fats, micro and macronutrients thus providing all the beneficiary nutrients to produce high-quality eggs and meat without any dose of antibiotics and hormones. BSF can be an alternative for recycling and valuing agro-industrial by-products as well. This review explains about the health benefits of using BSF as feed in aquaculture and poultry. This article also explains about the environmental impacts of using BSF. Thus, reviewing all the benefits of the usage of black soldier Larvae/ fly, it can be considered as the next solution for solid waste management in urban India as it has been approved by FDA.

Keywords: Black Soldier Fly, Larvae, Solid waste management, Poultry feed

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1. INTRODUCTION

Public health and pollution free environment are the main concerns of many developing countries; as a result, they undergo a considerable amount of adversities to maintain a serviceable solid waste management (SWM) system.¹ The unsatisfactory disposal and the lumpen rate of collecting the waste is a characteristic feature of the sewage waste management system, often seen in low and middle income countries. The phase at which the waste is collected ranges about 30% to 80%, although the waste collected was less than 50%. The wastes that are collected are disposed off in a controlled disposal site, whereas the remaining wastes are uncontrollably disposed. This is often observed as a normal activity in the rural parts in most of the countries.² Due to the uncontrolled disposal of wastes, there is a discharge of greenhouse gases (GHG) into the environment. It is noticed that methane is the main GHG emitted from landfills and wastewaters.³ Majority of the waste disposed from low and middle – income countries was found to be organic waste, also known as biowaste which involved kitchen wastes and residues from food industries and industries processing wood. The total waste production of biowaste in the low income countries as well as the middle – income countries reached about 50 to 70% in contrast to the production of waste from high – income settings, which reached around 20 – 40%.⁴ Black Soldier Flies (BSF, *Hermetia illucens*) belongs to the family of *Stratiomyidae* and are capable of breaking down organic matter and use it as their source of food. These wastes are consumed especially by the BSF Larvae (BSFL). Kitchen wastes contain the highest fats and calories when compared with other wastes, therefore BSFL favors kitchen wastes as its source of meal. As a result, those larvae that feed on kitchen wastes grow more in size than the other larvae.⁵ When compared to any other known species of its kind, BSFL has the capacity to break down and degrade larger quantities of organic waste in a faster and more effortless fashion. When BSFL was used as a way to rid off the organic wastes, it was noticed that the range of waste reduction was about 60 – 80%. BSFL can also be used as animal feed as they are made up of 40% protein and 30% fat.⁶ There are few organizations worldwide that produce BSF hatchlings as feed.⁷ Pesticides and mycotoxins are not absorbed by the BSF larvae and hence are breed on the by-products of cereal.⁸ BSF hatchlings are these days monetarily raised on grain side-effects.⁹ In any case, aside from farming side-effects, hatchlings could likewise be raised on animal fertilizer and family natural waste. In spite of the fact that development execution and meat nature of poultry benefited from BSF hatchlings raised on horse fertilizer have been recently explored, no examinations have been led till date to test on the off chance that BSF hatchlings could be raised on family unit natural waste and, at that point utilized as domesticated animal feed because of a few reasons, including limitation by sterile laws and absence of open acknowledgment.¹⁰ In any case, utilizing BSF that is raised on creature excrement and family unit natural waste as creature feed might offer a manageable method to reuse undiscovered assets in squander.¹¹ The preferred diet given to poultry is the BSFL meal as it contains more amounts of amino acids (lysine content- 40 – 45%) that is effortlessly digested and

increases the growth rate of the poultry. The larvae have big and brawny masticating apparatus that can cut down and degrade wastes, thereby digesting the organic compounds even before the compounds could decompose as result these larvae emit an odor. 1gm of eggs can digest about 10 kg of wastes per day. The developing advancement of cutting-edge hydroponics is carefully associated with a persistent quest for economical feed fixings ready to advance ideal fish development and government assistance. Aqua feeds have been for quite a while dependent on fish supper (FM) and fish oil (FO).¹² Although, these fixings speak to the perfect feed segments for fish, they are costly and regularly in low supply. Thus, a few distinctive elective fixings, specifically of plant origin, have been explored, and some of them are as of now utilized in aqua feed¹³. The BSF Larvae contains a diversity and macro and micronutrients that is ideal for human health and plays a very crucial role in the meat industry¹⁴. To reduce the quantity of solid waste without harming environment and the manure can be used as fertilizer and the larvae can degrade the waste as well, they can be feed to other animals' life chicken and fish.

2. LIFE CYCLE OF BLACK SOLDIER FLY

There are four phases in the life cycle of BSF: egg, larva, pupa, and adult stage as shown in figure 1. The pre – pupae which is the final step in the larval stage, shifts to a different location that is dry and appropriate for its transformation into the pupa stage. The fat stored during their larval stage is sufficient for their survival; and as they transform into adults, they survive only on water.^{15,16} The female BSF lays its eggs in and around the larval food source thereby reducing the transmission of pathogens from the waste to the eggs. BSF also reduces the bacterial and housefly population along with animal and plant waste pollution. The recycling process in BSF is done by converting the organic wastes into dairy manure, swine manure, vegetable waste, human food waste and poultry manure. The composition of BSF was found to be 40% protein and 30% fat after the recycle of the organic wastes. Depending on a variety of feeding materials, the accumulation of lipids varies in composition. The animal and aquaculture industry are now using BSF as its feed source. BSFL can be utilized as original raw materials in biological processes as well as in the production of biofuels.¹⁷

2.1 NURTURING OF THE BLACK SOLDIER FLIES

BSF are taken care of and grown in a separate set-up called the nursery. This process consists of 4 distinct phases:

Phase 1: The cages that are used to store the flies are used as a mating and an egg-laying chamber. (Fig. 2&3).

Phase 2: In this phase, the eggs that are laid in phase 1, finally hatches and are moved to the waste treatment process form the nursery set-up, when they are about five days old.

Phase 3: The remaining larvae that are left in the nursery are further taken care and fed till they reach their pre-pupae stage.

Phase 4: This is the final phase. There is formation of pupates. Once these pupae are fully developed into flies, they come out of the dark cages.

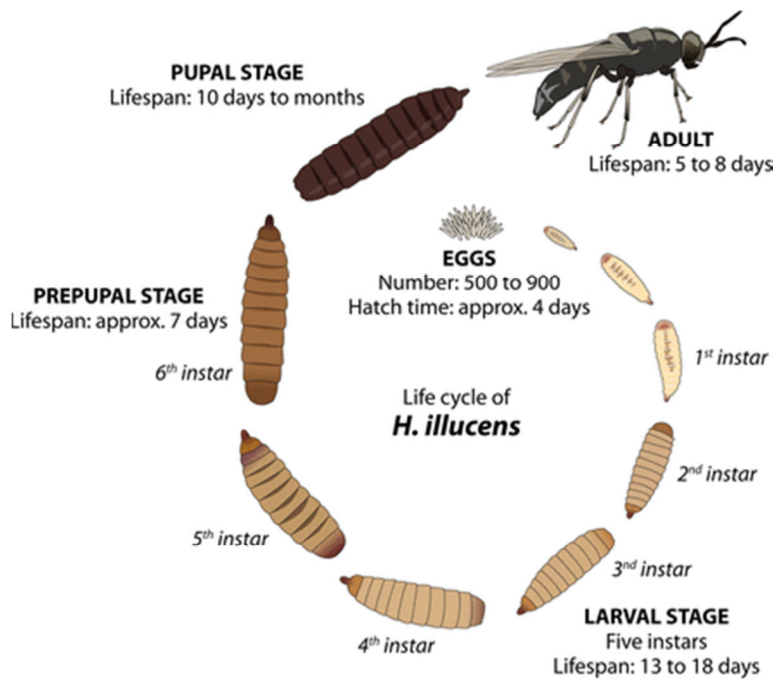


Fig 1. Different stage of BSF life cycle¹⁸

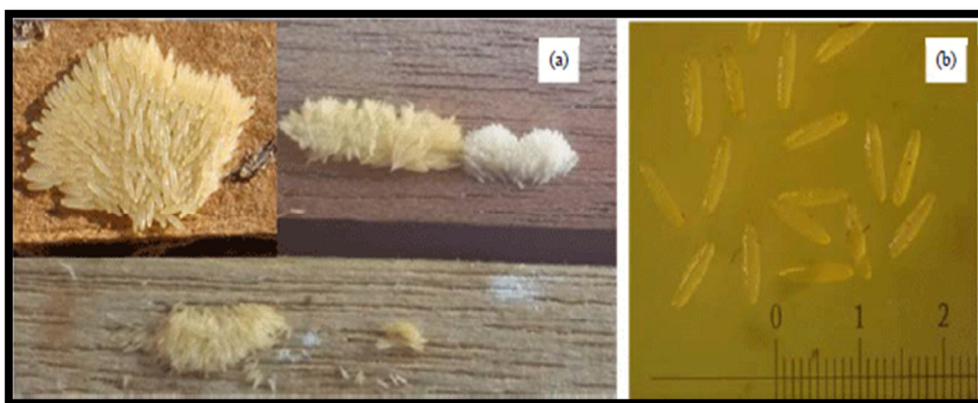


Fig 2. (a)- BSF egg clusters placed inside the ovitrap; (b)-observation of eggs under the microscope¹⁹

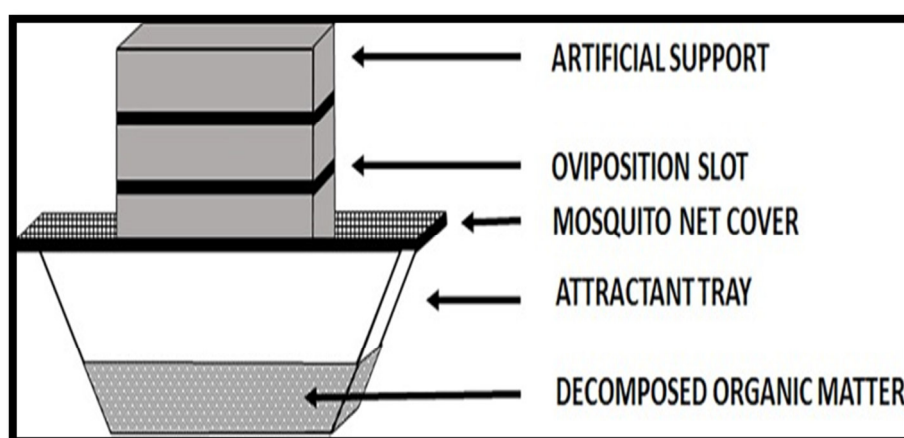


Fig 3. Artificial set-up for oviposition to collect eggs²⁰

Lighting and ventilation during the rearing is acquired from devouring the power supply. There ought to be a flow of natural air inside the rearing room and in this way, the ventilation will be well-established.³ The flies that are transformed to grown-ups are pulled into the electric lights, as result they relocate from the dim setting and confines to the mating setting. The mating settings are furnished with

water, manure, and an electric blender (attractant materials) which makes the pen appropriate for mating. For the initial five days, the hatchlings are taken care of with chicken feed and are left in the raising office till they come to their pre – pupae stage. They are brought from a hatchling's creation office and handle about six thousand pounds of waste everyday.¹⁰

2.2 PRE-PROCESSING

Bio wastes from family units were not involved in the BSF treatment plant facility; as a result, inorganic wastes were not in demand to be eliminated and hence there were no further arrangements required. It was observed, in order to eliminate the different types of bio-waste, the waste must be destroyed, however the bio-waste that was treated did not require a shredder.²¹

2.3 TREATMENT

The total number of days taken for the treatment process to be completed is about thirteen days. The tanks were filled with waste to a specific measure with a predefined number of five day old larvae, taken from the raising office.²² The larvae begin to consume all the wastes added to the tank and start their development process as they receive their nutrition. Every plastic box contains about 10,000 hatchlings and 15 kg of biowaste which is taken care of physically on three occasions.²³ On June 2016, a crusade was led in Sidoarjo, where they tested the waste and the gas from the tanks contained the hatchlings. It was tested for the presence of methane and nitrous oxide.²⁴

2.4 PRODUCT REAPING

After the culmination of 13 days, hatchlings are physically isolated from buildup utilizing a sifter. Thus, the blend of hatchlings and buildup is spread out onto the sifter, where then hatchlings slither through the strainer's gap to a beneficiary beneath to maintain a strategic distance from daylight.²⁵ The beneficiary is cleaned and the hatchlings are flushed off and gathered together. Gathered hatchlings are dunked into bubbling water. This water is now brought to overflow along with the condensed oil from that point, the hatchlings are sun dried.¹

3. BLACK SOLDIER FLY AS POULTRY FEED

BSF larvae (BSFL) is wealthy in amino-acids as it contains about 40% of proteins, more noteworthy than 28% of lipids and furthermore contains phosphorus and calcium as minerals²⁶ Fig. 4) Several feed has been listed in Table I which was given

along with BSFL and has been considered as a protein substitute to soybean and corn meals.²⁷ The soybean oil which is utilized as a nourishing variable in grilled chicken can be supplanted by the bug oil with no disregard to their supplement absorbability and development execution. The thickness and strength of the eggshells depended on the BSFL meal fed to laying hens. The shell of the egg would either increase or decrease in its thickness and strength when fed with defatted larvae.²⁸ Chitin is one of the main constituent that is found in the BSFL larvae meal.²⁹ Chitin being an indigestible component, when entered into the gut (cecum) of laying hens, activates the gut microbiota and initiates the production of short chain fatty acid (SCFA).³⁰ It was observed that the chitin content in the larvae stage was a little lower than that found in the pre-pupae stage.³¹ Lauric corrosive is a medium chain unsaturated fat and is perceived for its antimicrobial property in gut microbes. This corrosive is found in huge amounts in BSFL oil. At the point when the poultry was taken care of with BSFL oil, there was expanded ileal weight to length proportion at day 30 subsequent to incubating and expanded ileal stretched chain unsaturated fat and moderate measure of short chain unsaturated fats in multi day old ovens.¹¹ *Caed propionate* was found to be the most pompous in the BSFL oil bunch where as ileal propionate was most noteworthy in the coconut oil bunch at day 30. Sources for dietary fat influenced the organization of unsaturated fats in the stomach fat. Soaked unsaturated fats were found in higher sums in chicken eating regimens containing BSFL or coconut oil. These unsaturated fats were commanding over lauric and myristic acids when contrasted with the corn diet. Unexpectedly, an opposite pattern was observed, where polyunsaturated unsaturated fats were commanding over corn oil when contrasted with both the BSF Larvae and coconut oil. It was seen that coconut oil versus corn oil fundamentally builds the aggregate and high-thickness lipoprotein cholesterol though, BSFL oil versus corn oil expands the all-out cancer prevention agent limit in the chicken. In the event that 100 pounds of food squander is added to the container containing the BSFL, 20 pounds of pre- pupae will be obtained. A nourishing examination of dried dark officer fly pre-pupae comprises of: 42.1% rough protein, 34.8% ether remove (lipids), 7.0% unrefined fiber, 7.9% dampness, 1.4% nitrogen free concentrate (NFE), 14.6% debris, 5.0% calcium, 1.5% ph osphorus.³²

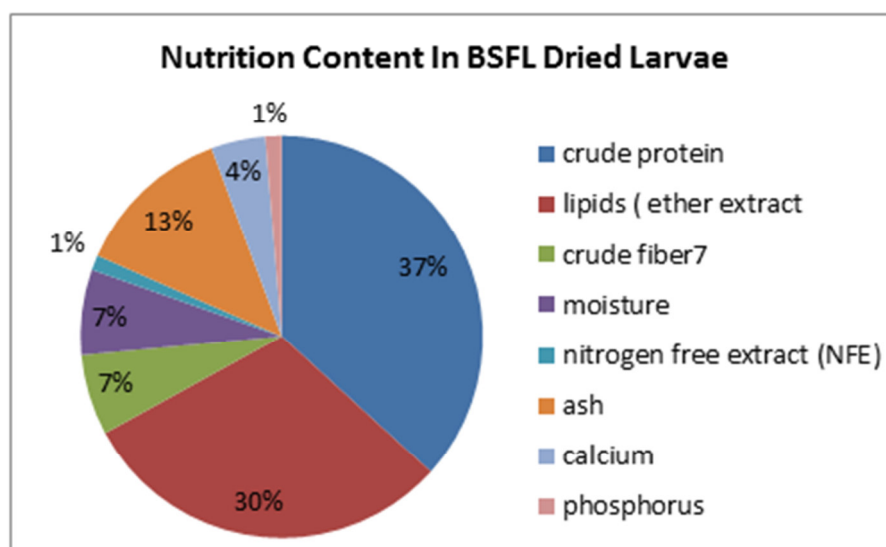


Fig 4. Nutrition content in dried BSF larvae³²

Table 1. Percentage of each feed given to control and experimental group ³² .		
Feed ingredients (%)	Control Group	Experimental Group
BSF Larvae	0.0	2.0
Soyabean oil	2.5	2.4
Corn meal	34.0	33.3
Essential Oils	0.1	0.1
Minerals	1.1	1.1

4. BLACK SOLDIER FLY AS FISH FEED

Escalated fish cultivating should be possible to utilize different fish suppliers. When contrasted with soya feast the BSFL dinner is wealthy in protein content. They give more basic unsaturated fat, for example, lauric corrosive which keeps gut from microbial contaminations.³³ As there is increment sought after fish than animals, we need to discover new wellsprings to take care of fish other than direct protein; hence we can utilize BSFL as fish feed which is popular these days. Its hatchlings can be raised on a wide scope of natural (squander) - material, lessen the volume of this loss by up to half, creating biomass with a protein substance of about 42% and a fat substance of up to 35 %.³⁴ The appropriateness of the BSF hatchlings supper as a protein source in feedstuff had been demonstrated in some warm water fish species. But in regards to rapacious cold-water species, restricted information is accessible; eg. on turbot and trout. It was noticed that, the nature of lipids and fat content had been modified in the fishes when their normal dietary meal (fish meal) was exchanged with insect meal, thus resulting in a change of taste of the fish fillets, although, 10-50% of insect meal did not have much effect in the fatty acid profile, flavor or aroma of the fish fillets as comprehended by the consumers.³⁵ For example, when 50% of BSF meal was fed to the Atlantic salmon or the rainbow trout, there were no alterations observed.¹² Utilizing BSF hatchlings as a halfway substitute for fish feed, could generously decrease the expense of fish creation in BG target regions since fish feed is the significant cost part of hydroponics. Accordingly, this innovation can possibly essentially improve the budgetary circumstance of the fish ranchers in the BG target regions by decreasing their dependence on business fish feed.³⁶

5. COMPOST PROCESSING

After gathering the hatchlings, the rest of the buildup is treated with soil, utilizing a similar methodology as common bio-waste fertilizing the soil as depicted in figure 5. The discharged esteems from fertilizing the soil were balanced for handling about 705 pounds of buildup after a direct extrapolation.³⁷ The expectation was that the buildup would show comparable emanations during the treatment of the soil as new bio-waste fertilizes the soil. As the buildup is incompletely debased from the BSF assimilation process, the fewer discharges that were analyzed could have been the new bio-waste that fertilizes the soil; hence the presumption might be overestimating the immediate emanations of buildup treating the soil. The office requires customary cleaning of all the gear. Vitality and the utilization of water were thought of. Collected hatchlings were accepted to be as a substitute to the current customary Peruvian fishmeal by a proportion of 2:1.³⁸ The proportion was legitimized as fishmeal which contained a normal of double the protein substance of hatchlings dinner on a wet weight premise. Vitality utilization underway procedure of fishmeal depending on the information gave furthermore transport via freight transport from El Callao-Peru to Surabaya, Indonesia and by lorry from Surabaya to Sidoarjo was additionally thought of. Thus fertilizing the soil office works on open constrained air circulation by treating the soil framework, with an ability to handle about 60 tons of bio-waste per-day. Considering utilization of vitality at this limit, the comparable vitality utilization at 1 ton of waste limit was assessed utilizing direct extrapolation.³⁹

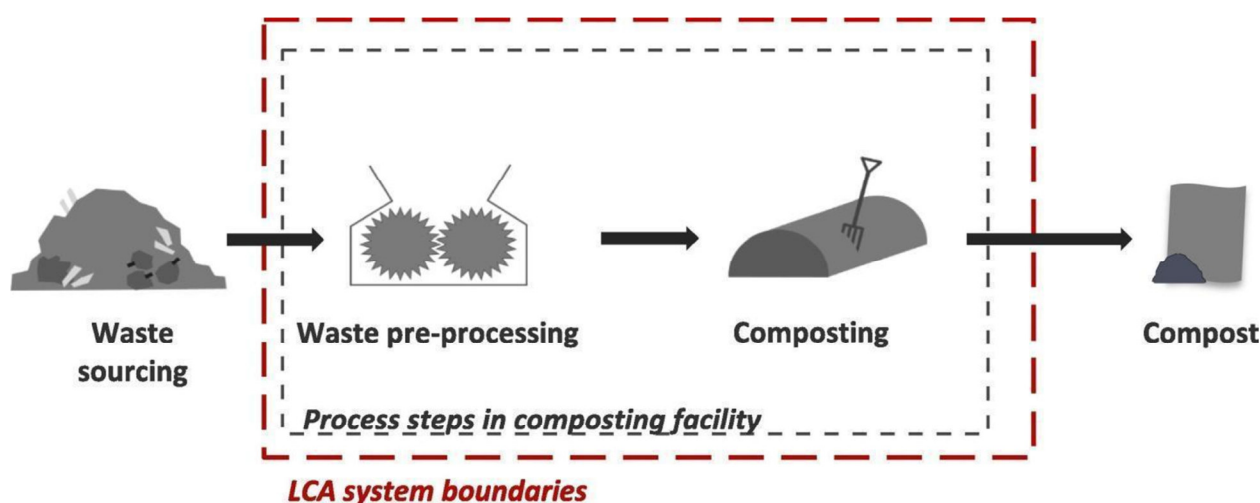


Fig 5. Schematic chart of the treating the soil framework considered³⁹

a. TREATMENT AND HANDLING OF WASTE

Low-middle income countries and high-income countries have unique ways of handling their organic wastes as it is

quite challenging especially for the low-middle income countries. Due to insufficient economic stature, low-middle income countries find it very formidable to maintain a proper waste management system.⁴⁰ The informal sector of the

waste management takes a greater share by bringing valuable waste in circulation. The business in the informal waste department seems to be thriving although the retrieval of sellable wastes is limited. Since only dry waste is collected and recycled, the organic waste is dumped on landfills or on illegal sites causing a threat to the health of the people living in and around the area.⁴¹ In order to overcome such adversities, a technology that could convert organic waste to valuable products will be appealing to the low-middle income countries. The decentralized municipal organic waste treatment facility conducted an experiment using BSF to treat organic waste and convert it to valuable products. Treating organic wastes with BSF in low-middle income countries will help enhance the quality of life and reduce health risks.⁴² Three main reasons to use BSF-technology as a treatment option:

1. BSF has the ability to reduce waste upto 80% as a result decrease the cost of waste transportation and landfills will no longer be in use. This will also stop the individuals from dumping wastes in open spaces which is commonly seen in low-middle income countries. The 20% waste that remains will be used as organic fertilizers on the soil, thereby making the land suitable to grow crops.⁴³
2. As the waste is digested by BSF, biomass is transformed into a high-quality animal protein that can be further used as feed for local fish and chicken farmers.
3. Using BSF-technology, the spread of zoonotic diseases from animals to humans are under control. Therefore, this technology is preferred to be used in farms or while treating wastes of animals.⁴⁴

6. ENVIRONMENTAL ADVANTAGES

The supplement substance and the mass substance of the pig excrement in use of Black soldier flies. They also provide efficiencies like poultry excrement, with good advantage of refined homestead freshness, decreased bug infestations and diminished contamination of supplement in spillover. In spite of the fact flies would not create lacking volumes to take care of the pigs, they can be diverted for different uses, for example, fish feed, and the rest of the excrement buildup is utilized for cultivation, empowering plants to develop additional inferior quality soils or even sand, once in a while.¹ In order to upgrade the quality of the larvae, BSFL are raised on dairy cow compost, mixing it with other materials. As a result, the leftover scrap decreases due to the presence of rich fiber present in the unadulterated dairy excrement

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which cannot be completely processed by the flies. It was observed that, BSFL can be reared on the blood from slaughterhouses and also on the entrails and internal organs of animals, giving value to the human food.²⁸ In this way, settled BSFL can be utilized to take care of numerous vertebrates and can utilize different vertebrate squanders as a substrate, without any impacts over the attractiveness of BSFL- as it took care of meat for people along with huge ramifications for feasible and a much lesser-input agribusiness in the creating scene. While the potential advantages are most noteworthy in these creating countries, BSFL and other creepy and crawly takes care of our jobs after some time in cutting edge economies, for example, the United States, because of vows to diminish squander among food combinations looking for endorsement from progressively ecologically cognizant purchasers and controllers, joined with the unstable costs of fish supper and other feed guiding makers to looks for alternatives.⁵

7. CONCLUSION

BSFL can be utilized for debasement of strong waste. After the debasement we can utilize the compost as manure. In growing nations like India, we can utilize such modest techniques and subsidizing can be raised without any problem. In any case, we are managing an innovation whose sensitive balance depends on black soldier fly. Be that as it may, dark fighter fly is an incredibly safe species equipped for managing requesting natural conditions, for example, dry season, food and lack of oxygen insufficiency. The examination says that the hens/chicken benefited from hatchlings and gave a more prominent number of eggs. The utilization of BSFL dinner as fractional substitution of basic feedstock of neighborhood oven chicken joined with propolis indicated recipient and acceptable gainful exhibitions, cadaver attributes and meat quality. Mix of both Natural and BSFL improves the well-being status of neighborhood oven chickens which may be given another system to grow a better nearby poultry industry.

8. AUTHORS CONTRIBUTION STATEMENT

All the authors have contributed significantly and tried their level best to highlight the present scenario towards solid waste management. The authors are listed based on the contribution level towards successful completion of the article.

9. CONFLICT OF INTEREST

Conflict of interest declared none.

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