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Review

The use of fly larvae for organic waste treatment

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ABSTRACT

The idea of using fly larvae for processing of organic waste was proposed almost 100 years ago. Since then, numerous laboratory studies have shown that several fly species are well suited for biodegradation of organic waste, with the house fly (*Musca domestica* L.) and the black soldier fly (*Hermetia illucens* L.) being the most extensively studied insects for this purpose. House fly larvae develop well in manure of animals fed a mixed diet, while black soldier fly larvae accept a greater variety of decaying organic matter. Blow fly and flesh fly maggots are better suited for biodegradation of meat processing waste. The larvae of these insects have been successfully used to reduce mass of animal manure, fecal sludge, municipal waste, food scrapes, restaurant and market waste, as well as plant residues left after oil extraction. Higher yields of larvae are produced on nutrient-rich wastes (meat processing waste, food waste) than on manure or plant residues. Larvae may be used as animal feed or for production of secondary products (biodiesel, biologically active substances). Waste residue becomes valuable fertilizer. During biodegradation the temperature of the substrate rises, pH changes from neutral to alkaline, ammonia release increases, and moisture decreases. Microbial load of some pathogens can be substantially reduced. Both larvae and digested residue may require further treatment to eliminate pathogens. Facilities utilizing natural fly populations, as well as pilot and full-scale plants with laboratory-reared fly populations have been shown to be effective and economically feasible. The major obstacles associated with the production of fly larvae from organic waste on an industrial scale seem to be technological aspects of scaling-up the production capacity, insufficient knowledge of fly biology necessary to produce large amounts of eggs, and current legislation. Technological innovations could greatly improve performance of the biodegradation facilities and decrease production costs.

Contents

1. Introduction . . . 69
2. Fly species suitable for biodegradation of organic waste . . . 69
   2.1. The house fly, *Musca domestica* L. . . . 69
   2.2. The black soldier fly, *Hermetia illucens* (L.) . . . 69
   2.3. The green bottle fly, *Lucilia sericata* (Meigen) . . . 70
   2.4. Face fly, *Musca autumnalis* L. . . . 70
   2.5. The common flesh fly, *Sarcophaga carnaria* (L.) . . . 71
3. Types of waste suitable for biodegradation by fly larvae . . . 71
4. Systems design . . . 71

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4.1. Systems exploiting natural fly populations . . . 71
4.2. Artificial rearing systems . . . 72
4.3. Mechanization of fly larvae production . . . 73
5. Advantages of biodegradation by fly larvae . . . 74
5.1. Production of fly biomass . . . 74
5.2. Waste management . . . 75
6. Economic analysis and commercial development . . . 76
7. Current problems and future perspectives . . . 76
7.1. Technological problems associated with scaling up of waste processing capacity . . . 76
7.2. Design and operation of fly biodegradation facilities . . . 77
7.3. Quality control procedures . . . 77
7.4. Legislative affecting insect-based waste processing . . . 77
8. Conclusions . . . 78
Acknowledgements . . . 78
References . . . 78

1. Introduction

Increasing world population has necessitated the development of intensive confined animal feeding operations to satisfy the growing demand for animal protein. Large farms producing significant amounts of manure and other agricultural wastes are often concentrated in small areas without enough land available for proper waste disposal. This contributes to nutrient imbalances which sometimes result in deteriorating soil quality, water and air pollution (Westerman and Bicudo, 2005). Strict environmental regulations fostered considerable research into developing alternative waste management techniques. Sustainable agriculture depends on proper implementation of these new techniques.

Many insects naturally feed in organic wastes, incorporating the nutrients into their bodies and reducing the amount of waste material in the process. Coprophagous and carrion breeding flies play an important role in the recycling of organic matter in nature.

Lindner (1919) is probably the first who proposed the use of flies to recover nutrients, especially fat, from organic waste (human and animal excreta). Later, scientists showed that poultry manure may be artificially inoculated by house fly eggs, the newly-hatched larvae can be bred and harvested in a controllable manner and processed into meal fed to growing chicks (Calvert, 1979; Miller et al., 1974). Subsequent laboratory studies indicated that, despite relatively low yields of fly larvae (3.2% of fresh poultry manure on a wet basis), processing of manure by fly larvae is advantageous due to the high quality of fly protein, substantial reduction of manure mass, and conversion of manure residue into granular odorless material (Calvert, 1979; Morgan and Eby, 1975).

This paper summarizes currently available information about fly species and types of waste used for biodegradation, the technology of semi-natural and laboratory bioconversion systems, potential use and safety of the products and discusses the most recent advancement and perspectiveness of biodegradation of organic waste by fly larvae.

2. Fly species suitable for biodegradation of organic waste

Selection of suitable fly species is a very important factor determining success of biodegradation process. Size, behavioral characteristics, fecundity, duration of larval development, natural occurence in the selected waste, pest status, adaptability to laboratory mass-rearing, and any species-specific requirements (e. g. adult diet) should be considered when selecting the optimum fly species for bioconversion.

2.1. The house fly, Musca domestica L.

House fly is a cosmopolitan species accompanying humans and livestock from tropical regions to the coldest areas in the world.

Adults are 6–9 mm long and feed on sebaceous fluids and also on most of the substrates where oviposition occurs (Hogsette and Farkas, 2000). House fly larvae can feed on a wide variety of decaying organic substrates, including animal manure and feed (Hogsette and Farkas, 2000).

The larvae develop through 3 larval instars. They grow fast; under optimum conditions pupation may occur after 3–5 days and adults emerge after another 4–5 days (Hogsette and Farkas, 2000). Pupation generally occurs in the dry upper layers of larval substrate. The development in warm regions during summer may be as fast as 7–10 days from eggs to adult and may extend to 40–49 days in cold environments (El Boushy, 1991).

The reproduction potential of house flies is great (Table 1). Under laboratory conditions, a maximum lifetime female reproductive output has been estimated to reach 729 eggs at 25 °C and 709 eggs at 30 °C (Fletcher et al., 1990). Due to the high population density, under mass-rearing conditions the fecundity is lower, reaching on average only 200–400 eggs per female in a 15-day egg collection period (Pastor et al., 2011). High reproduction rates, easy rearing in the laboratory and short development make the house fly an ideal insect for mass-rearing purposes.

The major disadvatage of the house fly is its pest status. It is a nuisance to both the man and animals and has been shown to transmit many pathogens, including parasites (Förster et al., 2007, 2009). The house flies can easily disperse several kilometers from the point of release (Hogsette and Farkas, 2000).

2.2. The black soldier fly, Hermetia illucens (L.)

Originally native to the Americas, the black soldier fly has been introduced to subtropical and tropical regions all over the world. Adults are large, conspicious black flies up to 20 mm long. Larvae develop through 6 larval instars and generally grow to 18–20 mm (Rozkošný, 1997).

Adults are not strong fliers and spend most of the day resting on vegetation. Black soldier fly flourish at warmer temperatures, with almost all oviposition occuring at >26 °C (Tomberlin and Sheppard, 2002). Under laboratory conditions (greenhouse) mating usually occurs 2 days after eclosion and oviposition 4 days after eclosion (Tomberlin and Sheppard, 2002). Eggs are usually laid in crevices in dry locations near the larval substrate. Larvae can develop on a wide range of decaying plant and animal matter, including manure, food scrapes, municipal garbage, and rotting plant material (Diener et al., 2011a; Sheppard et al., 1994). Development of the