THE BLACK SOLDIER FLY, *HERMETIA ILLUCENS*, AS A MANURE MANAGEMENT / RESOURCE RECOVERY TOOL

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ABSTRACT

Insects play a significant role in recycling many forms of waste and other accumulated nutrients in the environment. Attempts to harness the power of insects for manure management have not been particularly successful or widely adopted. Although additional research is needed, the current state of the technology for utilizing the black soldier fly (Hermatia) for processing hen and swine manure appears to make it commercially feasible. Hermetia consume manure and convert the nutrients into larval insect mass, which contains 40+% protein and 30+% fat; thus a potential high protein, high energy animal feed. In the process, manure mass is reduced about 50%, with even greater reductions in N and P mass. Additional environmental benefits occur, and a recent analysis suggests that Hermetia manure management could increase net revenue by $25,000! per year per layer house. For all applications, needed improved technology is associated with the adult life cycle and providing eggs throughout the year, and providing a warm environment for the larvae during winter. For conventional swine barn applications, economical methods for removal of excess liquid (urine) are also needed.

KEYWORDS. Hen manure, Swine manure Nutrient reduction, Bio-processing, Value-added, Insects

INTRODUCTION

Insects, especially various fly larvae (maggots) and some beetles, readily feed on fresh manure, converting residual protein and other nutrients into their biomass, which can be a high quality animal feedstuff. Considerable research has been conducted to understand this activity in order to exploit it for manure management. Lately, the emphasis has shifted from feedstuff production to potentially using insects to solve problems associated with the large amounts of manure produced at animal feeding operations (CAFOs). While incorporating and concentrating nutrients from manure into more valuable biomass (animal feedstuff), insect larvae reduce the nutrient concentration and bulk of the manure residue, thus reducing pollution potential 50-60% or more. As an added benefit, while occupying the manure they aerate and dry it, reducing odors. In addition, as a result of consuming and digesting microorganisms and the production of bacteriostatic, bactericidal, and/or fungicidal compounds in many species (Landi, 1960; Hoffmann and Hetru, 1992; Natori,1995; Sherman et al., 2000), maggots modify the microflora of manure, potentially reducing harmful and undesirable species. This has been shown to occur with black soldier fly, potentially reducing harmful bacteria (Erickson, et al., 2004). Production of high-value feedstuff and reduction of the mass and pollution potential of the manure are the returns for good management of such a system.

While past research, and modest size demonstrations, have shown the potential of insect systems, they have not been adopted beyond some essentially subsistence situations. Three of the most important reasons for the lack of adoption include difficulties in adapting insect culture to modern animal production facilities, difficulties in producing eggs or larvae consistently on a year round basis, and effective, low cost methods for cold weather operation.

The black soldier fly (Hermetia illucens) (Hermetia) is a native insect common to the southeastern United States. Adults live and mate near larval habitat. Hermetia is not recognized as a pest because the adult is not attracted to human habitation or foods (Furman et al. 1959). Adults do not need to eat, surviving on the large fat body stored from the larval stage. The larva of Hermetia is a voracious consumer of decaying organic matter including kitchen waste, spoiled feed, and manure. They flourished in open-sided caged layer houses that, in the past, were common in the southern U.S. In these situations soldier fly larvae were present by the millions, but only a few ovipositing females were observed. These unmanaged populations eliminated house fly breeding and reduced manure residue, but feedstuff harvest was never attempted. Prepupae harvest from managed Hermetia populations could be a viable addition to confined livestock enterprises.

HERMETIA MANURE MANAGEMENT SYSTEMS

The simplest Hermetia manure management system utilizes wild fly populations to digest the manure. The larvae occur in very dense populations on organic wastes as diverse as manures, coffee bean pulp, vegetables, catsup and carrion. Mature larvae (prepupae) can be harvested and used as a feedstuff. The Hermetia system developed by Sheppard et al. (1994) converted poultry manure to a 42% protein, 35% fat feedstuff at an 8% dry matter conversion rate (Sheppard et al., 1994). This system also controlled house flies (Sheppard, 1983) and reduced manure volume by 50% (Sheppard 1983), including a 24% reduction in total nitrogen concentration (62% reduction of N mass) (Sheppard et al., 1998).

Hermetia are most easily managed directly under caged layers (or other animals) in concrete basins. No separate facility or special equipment is needed for production or harvest. This is possible because of the migratory habits of the prepupae. This migration occurs because larvae need to leave the manure to successfully pupate to an adult. At this stage they are at their maximum size, with a large store of fat to sustain them through metamorphosis. Migrating prepupae have evacuated their digestive tract and no longer feed, but use their mouthparts to pull their body along in the quest for a safe pupation site. Pupation takes a minimum of 10 days so collections can be stockpiled prior to processing or utilization. In a 5-month Hermetia season a 100,000 bird caged layer house could produce 48,000 kg of prepupae suitable for feed. Many of the difficulties associated with utilization of Hermetia for manure processing in enclosed animal facilities, and for other animals, including swine and dairy calves, have been resolved, although additional improvements would allow widespread adoption of the system.

Swine System One

Recent developments in rearing Hermetia allow for waste management in fully enclosed buildings (Figure 1). Swine waste collected by conveyor belt was separated into manure solids and urine plus excess water. Collected manure solids were delivered to the larval culture basin. The larval culture basin contained 85,000 to 100,000 mixed aged larvae/m^2. A 35^o ramp along opposing walls of the manure pit directed the migrating prepupae to a gutter at the top. This gutter directed prepupae to collection containers. A portion of the prepupae were saved and used to support the adult soldier fly colony. Eggs from the adult colony were used to maintain larval densities sufficient to digest the manure. The remaining prepupae were dried and processed for rendering or feed preparation. The digested swine manure could undergo further treatment or be land applied as a soil amendment.

Experimental Results

Eighteen pigs were housed over a manure collection belt during the grow-finish period. Manure was removed once per day and distributed over a culture basin containing mixed age Hermetia larvae. Over the course of the trial, manure mass total solids was reduced by 56% compared to fresh manure. The composition of the self-harvested prepupae is shown in Table 1, and the composition of the residue remaining after larval culture, compared to the sampled fresh manure is shown in Table 2.

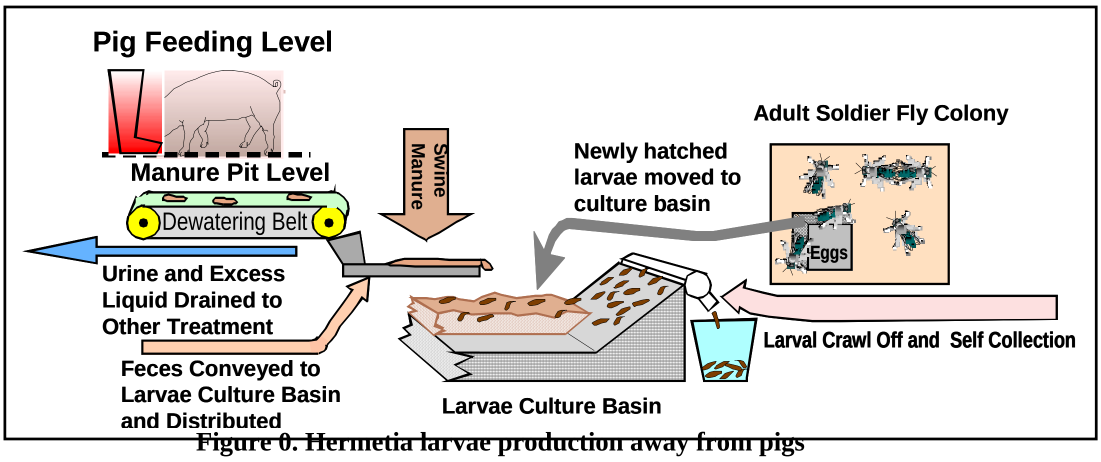


Figure 0. Hermetia larvae production away from pigs

Table 1. Essential amino acid, mineral, and nutrient content of Hermetia prepupae fed on swine manure.

Essential Amino Acids (%)		Mineral and Other	
Methionine	0.83	P	0.88%
Lysine	2.21	K	1.16%
Leucine	2.61	Ca	5.36%
Isoleucine	1.51	Mg	0.44%
Histidine	0.96	Mn	348 ppm
Phenylalanine	1.49	Fe	776 ppm
Valine	2.23	Zn	271 ppm
l-Arginine	1.77	Crude protein	43.2%
Threonine	1.41	Ether extract	28.0%
Tryptophan	0.59	Ash	16.6%

Table 2. Composition of fresh pig manure compared to the residue remaining after Hermetia culture.

	Pig manure		Hermetia residue		Change
Element	ppm	SEM	ppm	SEM	%
N	923.7	44.4**	414.52	6.17	-55.1
P	676.2	37.9**	378	13.1	-44.1
K	358.7	19.8**	169.34	7.07	-52.8
Ca	969.3	62.5**	425	19.4	-56.2
Mg	299.3	16.9**	175.96	7.08	-41.2
S	80.31	4.33**	44.44	1.38	-44.7
Fe	6.63	0.31^{ns}	6.8	0.54	+2.6
Mn	12.8	0.75**	6.02	0.23	-53.0
Zn	23.53	1.09**	12.91	0.39	-45.1
Cu	14.85	1.45**	8.05	0.32	-45.8
B	0.32	0.02**	0.16	0	-50.0
C	11,248	497**	4,232.6	36.8	-62.4
Na	99.93	5.59**	48.15	2.04	-51.8

** = significant at P< 0.001, One way ANOVA, Minitab 1997; ns = not significant.

The results presented in Table 1 illustrate the potential for Hermetia prepupae to be used as a feed ingredient for most domestic animals. The composition of the prepupae was similar to that in earlier trials, except that the lipid content was somewhat lower (28% compared to 32-36%).

The comparison of fresh manure with the residue remaining after larval culture (Table 2) shows that the concentrations of N and minerals, with the exception of iron, were drastically reduced by the feeding larvae. If the 56% reduction in the mass of the total solids is taken into account, total mass reductions for many of the elements shown in Table 2 were near 80%. Compared with fresh manure, much less crop land area would be needed to manage the residue, compared to manure.

Swine System Two

If urine and spilled water can be drained or diverted, Hermetia larvae can be cultured directly beneath pigs housed on slatted floors. Such a system would appear to be readily adaptable to pigs housed in high-rise buildings. A combination of slotted and screened standpipes and laterals within the basin (based on the Ozyboyd Vertical Drainage Bed) has been found to be acceptable for excess liquid removal. These drains are attached to pipes beneath the floor, and can be removed for basin cleaning. The second system for culture on swine manure is illustrated in Figure 2.

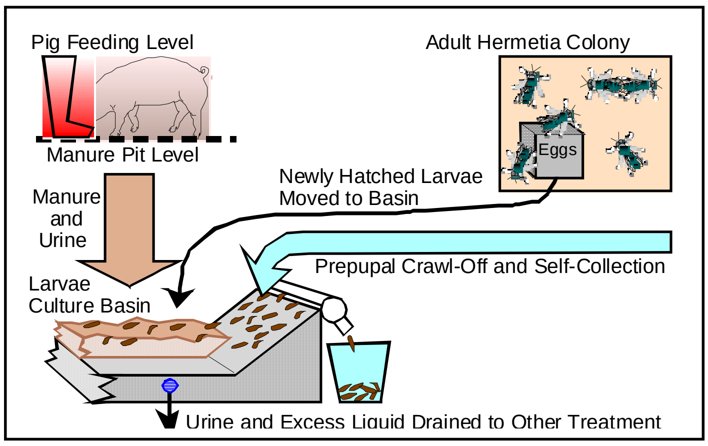


Figure 2. Culture of Hermetia larvae directly beneath pigs.

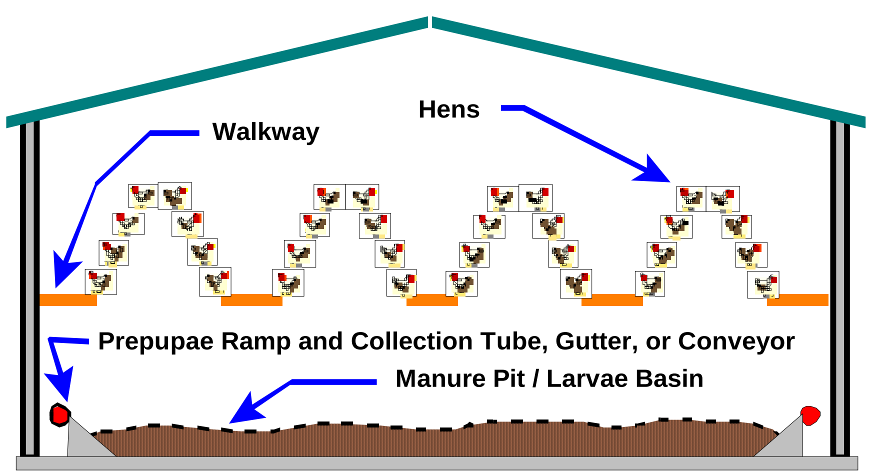
Experimental Results

During summer 2004, two manure basin liquid removal systems were tested. Both systems were tested with two pens of six pigs each (initial wt., 21 kg), housed over the individual basins. Treatment 1 consisted of 16 slotted and screened standpipes plus 4 slotted and screened laterals while treatment 2 was a double system with two sets of stand pipes and laterals with discharges that were alternately opened or closed at 14 day intervals. Alternately opening and closing the drainage system actually resulted in more "blinding" and restricted flow than leaving the drainage system open continuously.

During the grow-finish period, larvae collections were 0.214 kg/pig/day for treatment 1 and 0.153 kg/pig/day (P<.03) for treatment 2 (including the first 4-5 weeks when the larvae population was being established and essentially no prepupae were collected). Equivalent prepupal collections would equal to 64,000 kg/year for a 1,000 head finishing house having 2.5 turns of pigs/year.

Layer Hen System

Much of the interest in the use of the black soldier fly for manure processing and house fly control was prompted by observations of natural populations in old-style, open sided layer houses. The evolution to newer type housing for laying hens eliminated most of the wild Hermetia population within hen houses. However, it should be possible to introduce controlled populations of Hermetia to high-rise hen houses in order to process the manure into a lower nutrient, soil amendment and a high value feedstuff. This has been demonstrated in a small pilot scale house and proposed designs have been developed for full scale houses. The general design for such a house is shown in Figure 3.



Figrue 3. Hen house with Hermetia manure processing.

It should be possible to integrate the rearing of Hermetia adults and natural distribution of larvae, as well as single point collection of prepupae (using small conveyor belts) into the design of a layer hen house. Small greenhouses, for Hermetia adults, could be distributed along the south wall of the hen house. A partial cross section of such a house is shown in Figure 4.

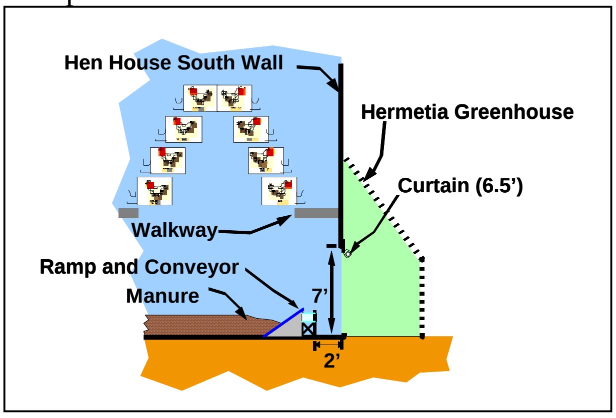


Figure 4. Hen house with integrated Hermetia reproduction and automated prepupae collection.

In operation, such a hen house could be used for Hermetia prepupae production year around. The prepupae collection conveyors (one on each side of the house, plus a cross conveyor) would be operated for a few minutes per day. Prepupae would be deposited into a hopper leading to a dryer. Once per week an aliquot of prepupae would be moved to the greenhouses (about 2 x 4 m, located about 30 m apart) where they would be allowed to pupate and become the next generation of breeding adults. Temperature within the greenhouses would be controlled by operating curtains between the hen house and greenhouses, plus a small fan would likely be needed. If dried prepupae could be sold for $330/1000 kg, it has been estimated that Hermetia processing would return a net of $25,000! per house per year above conventional manure management.

UTILIZATION OF COLLECTED PREPUPAE

Dried prepupae have been fed experimentally to chicks, pigs, and fish, and to frogs in the live state. In general, use of Hermetia meal has been successful, but some problems in balancing diets, when used at higher levels, as a result of high fat content have been observed. This suggests that the best use of the product may likely be as a partial substitute for other protein supplements, or that the prepupae should undergo additional processing, such as rendering. As shown in Table 3, feed efficiency and gain were not different when catfish fingerlings were fed a diet in which 25% of the menhaden fish meal was replaced by prepupae meal. Menhaden fish meal usually has a market value around $550 per 1000 kg.

Table3. Feed efficiency and weight gains of channel catfish fingerlings fed Hermetia prepupal supplemented diets, and compared with a commercial diet control.

Diet	1	2	3	4	5	6 (Control)
Replacement rate (%)	0	25	50	75	100	NA
Feed/Gain	1.87[a]	1.96[a]	2.29[b]	2.31[b]	2.55[c]	2.2[b]
Gain/Fish(g)	17.96[a]	17.27[a]	14.94[b]	15.94[a]	13.68[c]	15.90[b]

[a, b, c] Means with different superscripts are different, P<0.05.

CONCLUSION

The black soldier fly holds much promise for converting low value manures and many other organic "wastes" into a valuable commodity. Systems for layer hens and swine are relatively well developed, although improved technology for maintenance of breeding populations and supporting larval growth and development in colder climates or during winter are needed.

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