PROCESSING OF MANURE AND OTHER PERISHABLE ORGANICS AND WASTE INTO VALUABLE FEED NUTRIENTS AND OTHER COMPONENTS

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Value Added Waste Management with Black Soldier Fly

Hermetia illucens – The Black Soldier Fly

- Worldwide distribution.
- Synanthropic larvae.
- Adults in wild habitat. Common but most people never see the adults. They will not enter a dwelling or closed building.
- No human disease transmission.

Larvae Develop Huge, Dense Populations in Nature

-1’000s of square feet of larvae in a solid layer in old caged layer hen houses.

-Similar populations in open air swine houses delayed manure removal for years.

- We can harness this natural process, and capture the high quality nutrients that would escape with the migratory prepupae, for the benefit of humans.

Soldier Fly Larval Digestion Decreases Malodorous Compounds

	PERCENT DECREASE AT:		
COMPOUND	4 hr	20 hr	48 hr
Butyric Acid	52	87	100
Valeric Acid	44	85	100
Caproic Acid	37	87	100
Furfural	55	51	60

Intensively Managed Black Soldier Fly for Nutrient Recovery

-Up to 2 lb larval mass per sq. ft.

-Feedstock up to 2X larval mass per day.

- Convert many perishable organics at 25% d.m. efficiency.

Feedstocks for digestion with Soldier Fly

(Feedstock must be fresh)

- **Food waste, includes dairy, meat**
- **Swine manure, poultry**
- **Wet brewers grains**
- **Palm kernel meal**

Products from Soldier Fly Larvae/Prepupae

Whole dried and ground for feedstuff, compares favorably with fishmeal @ up to $1200 per ton.

-Protein and separated oil.

-Chitin.

-Digested residue is an excellent Soil amendment, and vermiculture media.

- Antibiotics?

Costs of Prepupae Meal vs Fishmeal

-Over 1 vessel-ton-week to harvest 1 ton menhaden (25% d.m.)

-Prepupal production costs assumed lower

-44% d.m. prepupae less expensive to dry

-Prepupae production solves other environmental problems – landfill avoidance; excess nutrients on livestock farms

Food Security

-A more affluent world population is bidding up animal protein prices.

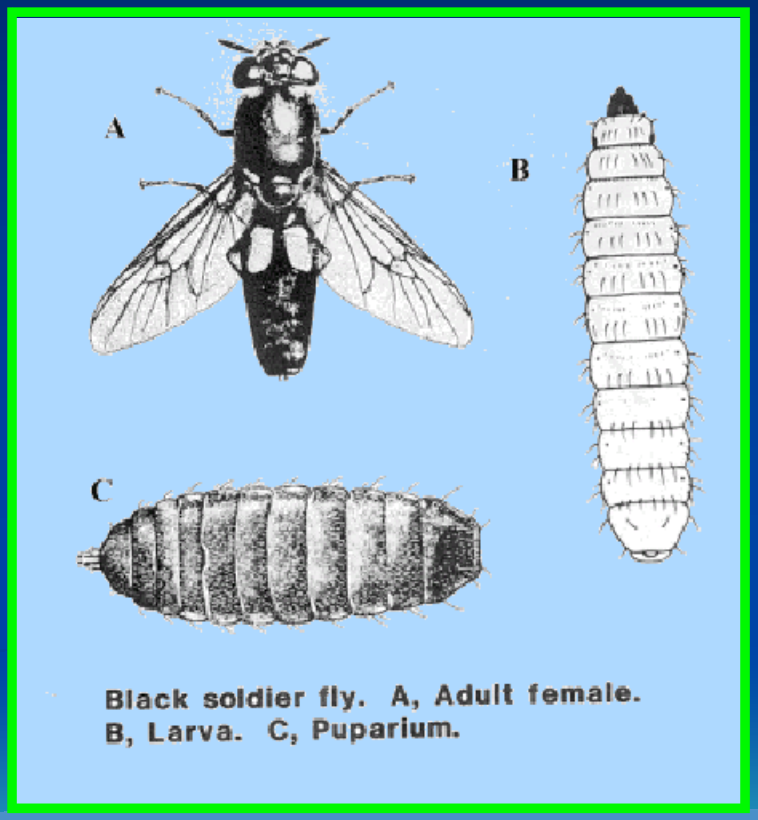
-Fishmeal supply decreasing, price increasing, constraining aquaculture.

-Improved food security for the world's population will release people to address pressing environmental issues.

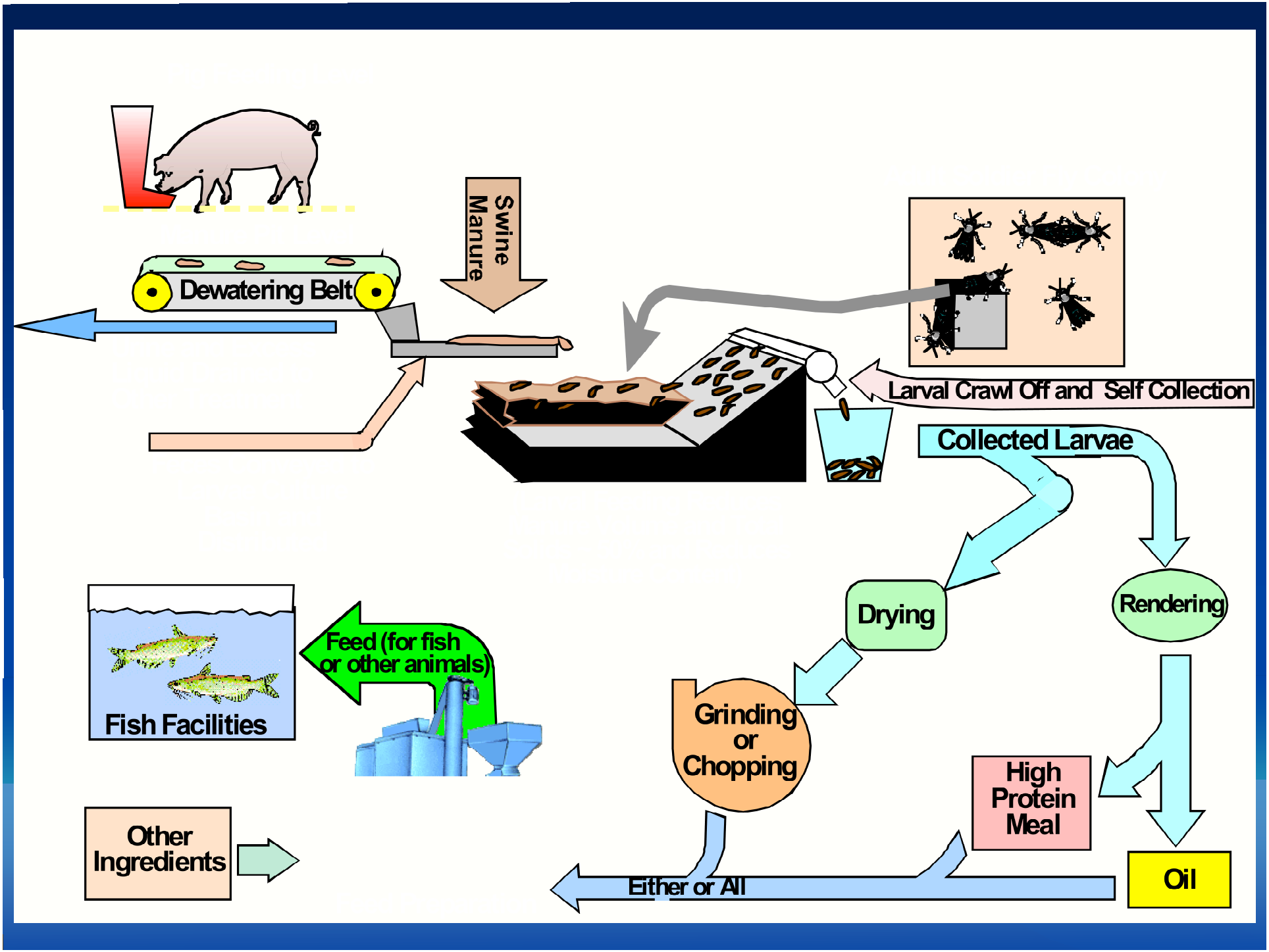
- Robust prepupae production will help.

The Black Soldier Fly, Hermetia illucens, as an Organic Waste Resource Recovery Tool

D. Craig Sheppard and G. Larry Newton, University of Georgia



Black soldier fly. A, Adult female. B, Larva. C, Puparium.

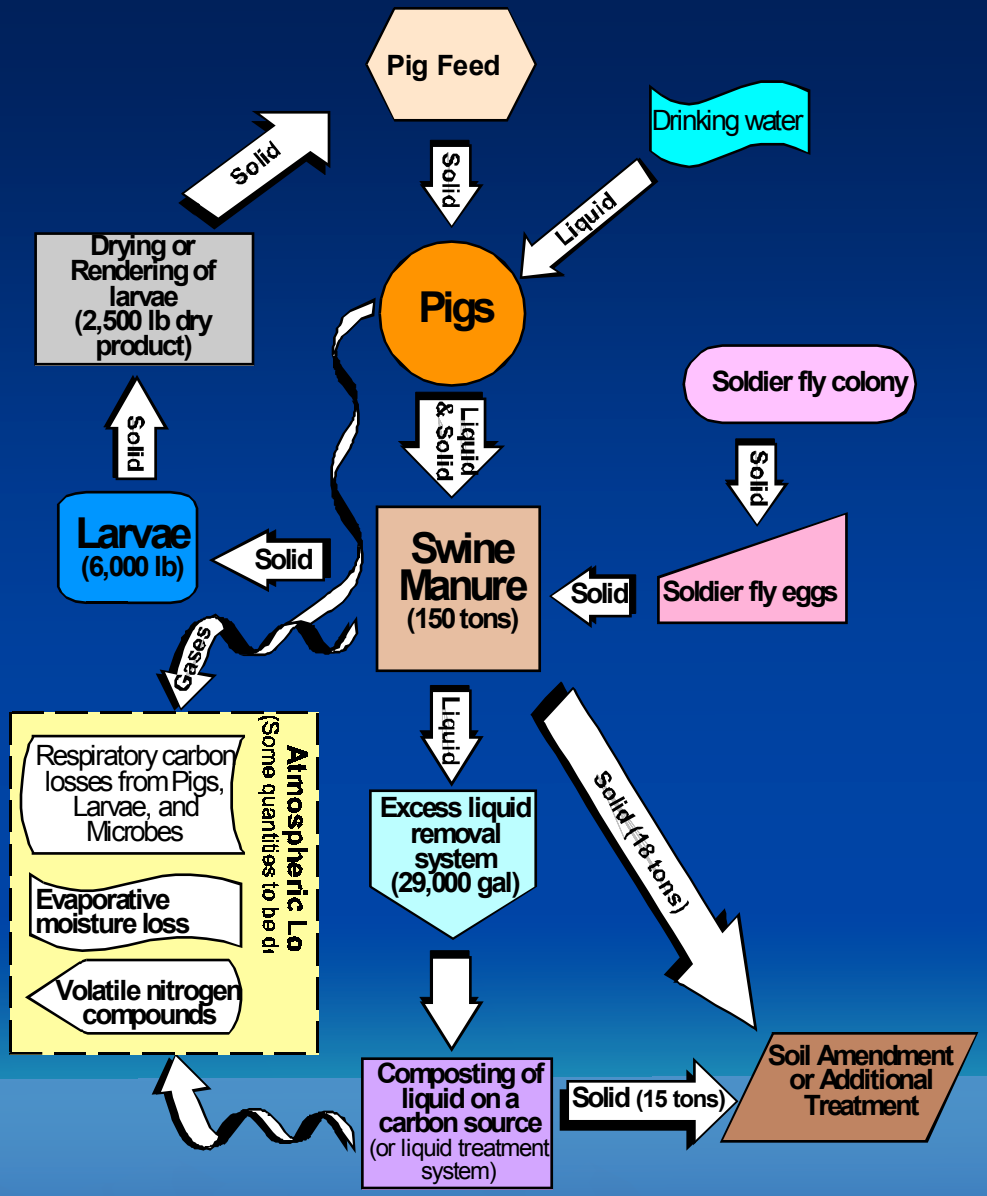

Swine Manure
Dewatering Belt
Larval Crawl Off and Self Collection
Collected Larvae
Drying
Rendering
Grinding or Chopping
High Protein Meal
Oil
Either or All
Feed (for fish or other animals)
Fish Facilities
Other Ingredients

Raising Black Soldier Flies Under Pigs

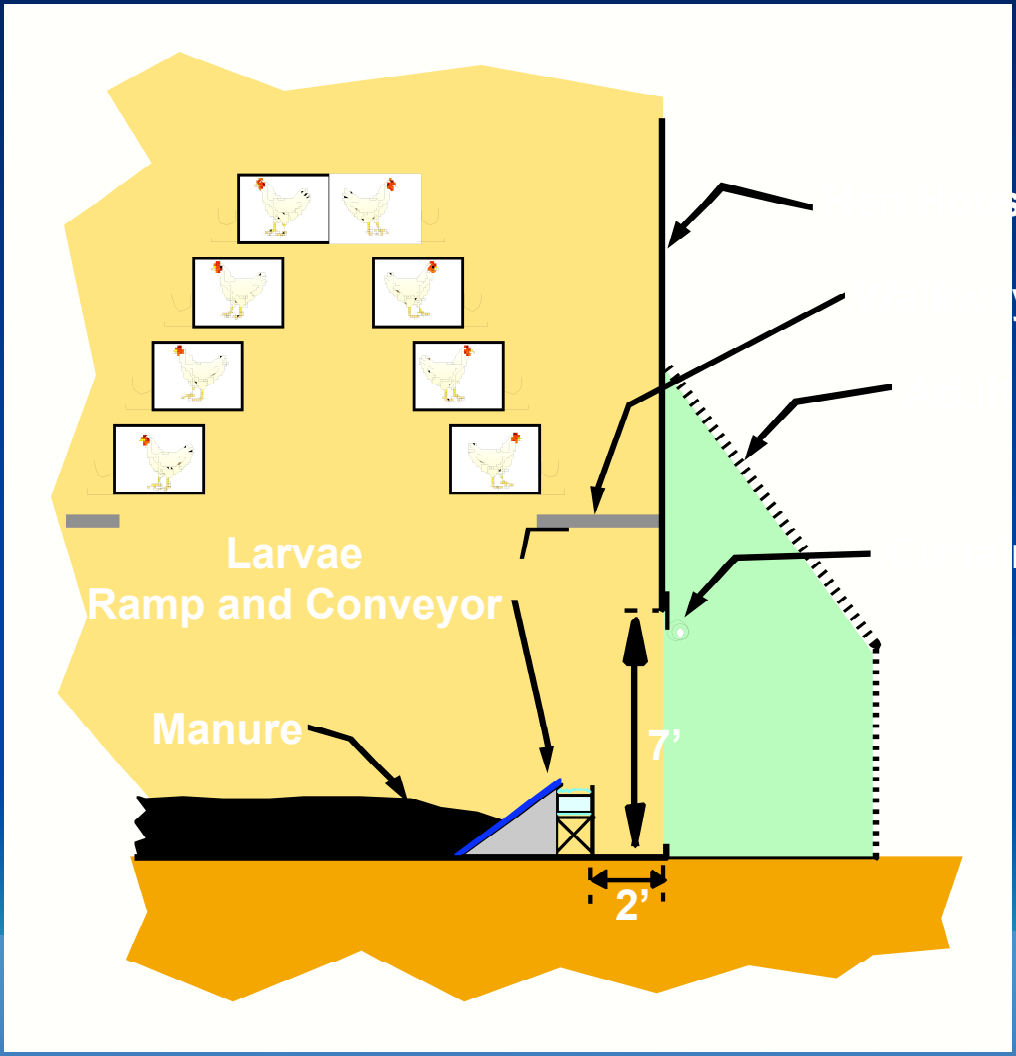

Dense Larval Population Under
Dunging Area of Pen

Flow Diagram

Quantities are estimates per 100 grow-finish pig places and 3.5 turns per year.



Partial Cross Section of High-Rise Hen House



se South Wall

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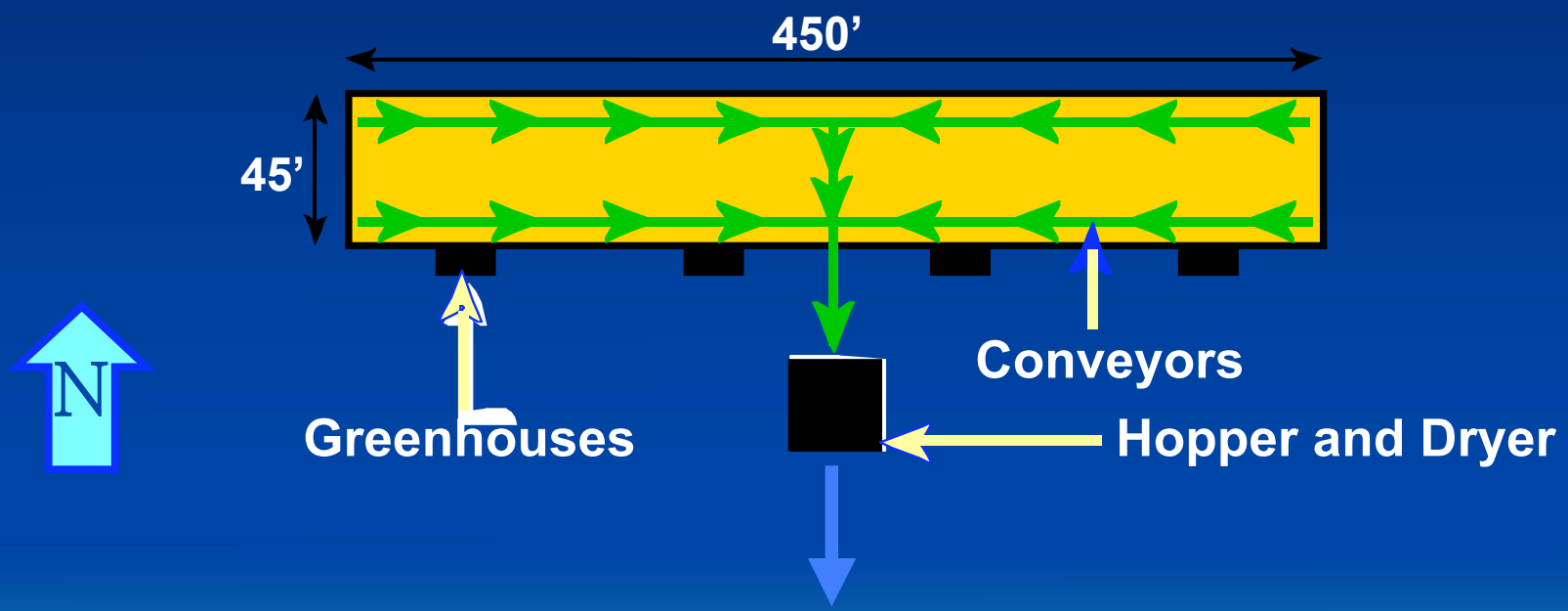
Hermetia Greenhouse

n (6.5’)

From:
Erin Thelen
Michigan State

Potential Layout for Automated Hermetia Production in a Hen House



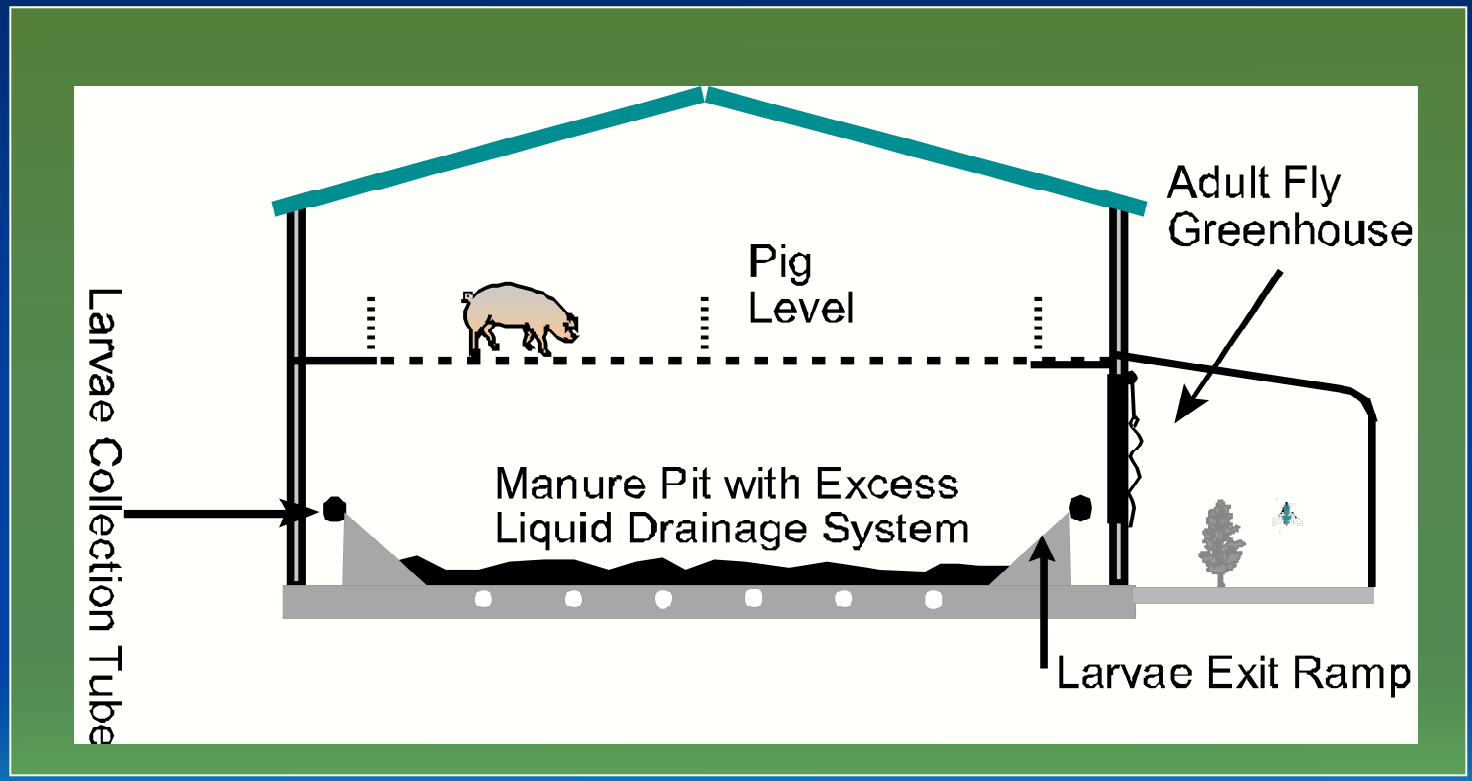
From:
Erin Thelen
Michigan State

Calculated Economic Results for Layer Houses

- ►Installation Costs Are Expected to be $55,00 to $60,000 / House.
- ►Yearly Operating Costs Are Expected to Increase by $2,000 / House.
- ►Yearly Manure Sales Are Expected to Decrease by $12,000 / House.
- ►Yearly Sale of Dried Hermetia Prepupae (at $300 / ton) Are Expected to Return $40,000 / House.
- ►Net Returns Are Expected to Increase by $25,000 to $27,000 / House / Year for a payback period of about 2 years.

From:
Erin Thelen
Michigan State

A Similar System for High-Rise Swine Houses Has Been Proposed



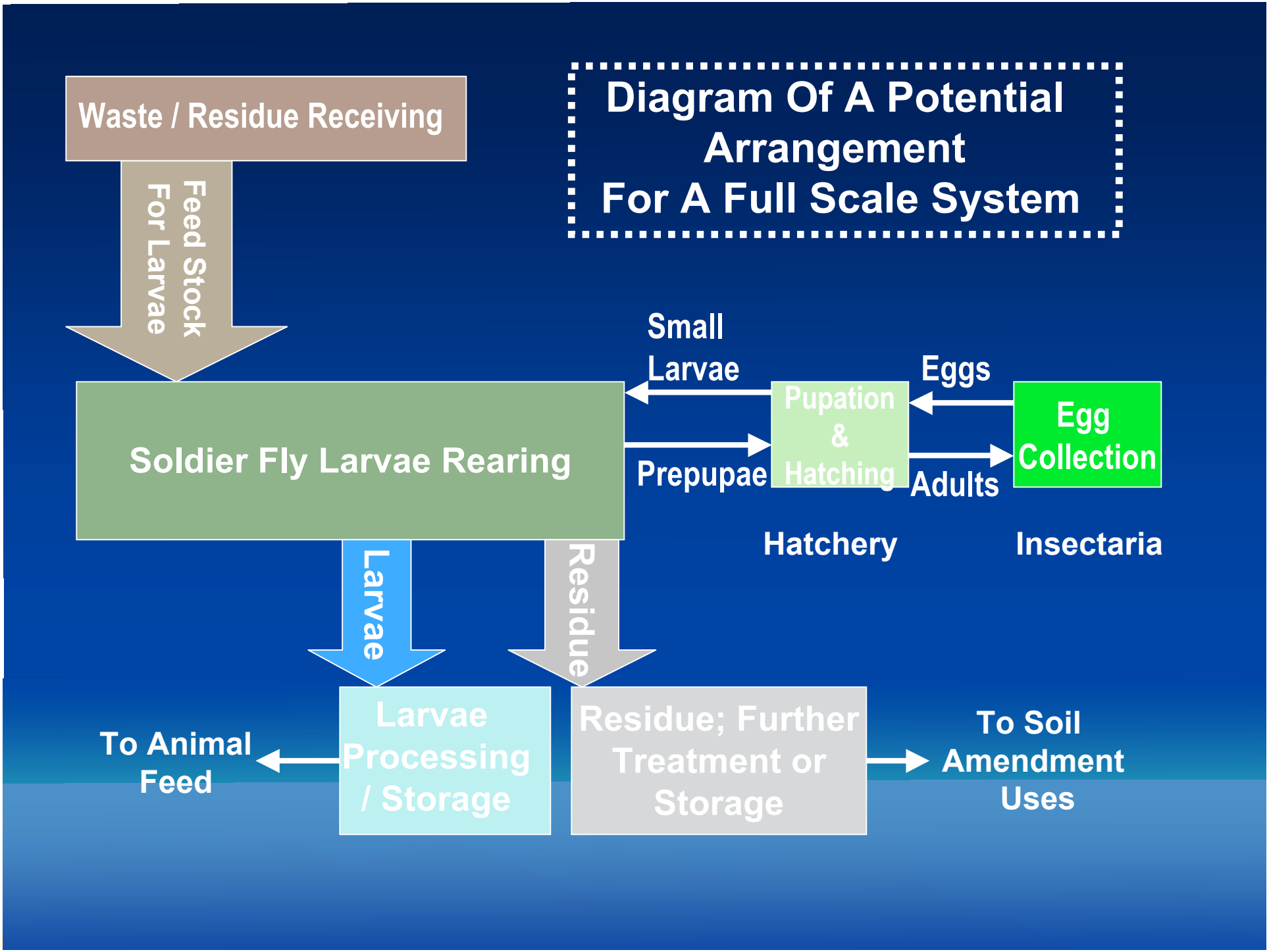


Diagram Of A Potential Arrangement For A Full Scale System
Waste / Residue Receiving
Feed Stock For Larvae
Small Larvae
Eggs
Soldier Fly Larvae Rearing
Pupation & Hatching
Egg Collection
Prepupae
Adults
Hatchery
Insectaria
Larvae
Residue
To Animal Feed
Larvae Processing / Storage
Residue; Further Treatment or Storage
To Soil Amendment Uses

Nutrient Comparison of Black Soldier Fly Digested Swine Manure and Fresh Manure

Element	Fresh Pig Manure	Hermetia Residue	% Mass Change Of Element
	(ppm)	(ppm)	
N	923.7	414.52 **	-77.6
P	676.2	378 **	-72.0
K	358.7	169.34 **	-76.4
Ca	969.3	425 **	-78.1
Mg	299.3	175.96 **	-70.6
S	80.31	44.44 **	-72.3
Fe	6.63	6.8^{ns}	-48.7

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

Elemental Comparison of Black Soldier Fly Digested Swine Manure and Fresh Manure (continued)

Element (or Item)	Fresh Pig Manure (ppm)	Hermetia Residue (ppm)	% Mass Change Of Element (or Item)
Mn	12.8	6.02 **	-76.5
Zn	23.53	12.91**	-72.6
Cu	14.85	8.05**	-72.9
B	0.32	0.16**	-75.0
C	11,248	4,232.6**	-81.2
Na	99.93	48.15**	-75.9
Soluble Salts	457.80	714.00**	-22.0
pH (units)	6.24	7**	
C:N (ratio)	12.2	10.22**	

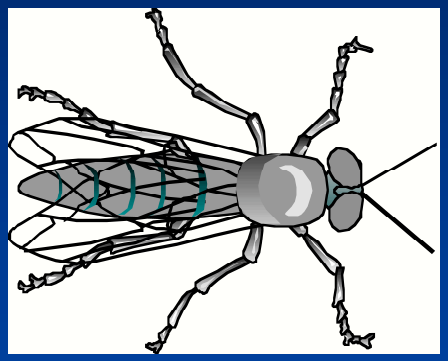
** = significant at P≤ 0.001, One way ANOVA, Minitab 1997

Soldier Fly Larvae Are High Quality Feed

Feedstuff from Hermetia:

Composition

43-44% Dry Matter
42-48% Protein (dry basis)
30-36% Fat (dry basis)
4-5% Calcium (dry basis)
0.7-1.5% Phosphorus (dry basis)



- The Protein Is A High Quality Animal Protein With Good Amino Acid Balance.
- The Fat Contains Desirable Mono-unsaturated Fatty Acids And Can Have Significant Quantities Of Natural Colored Pigments (depending on their feed).
- The Prepupae Are Relatively Low In Moisture, Making Drying Practical. Wet Feedstuff Can Also Be Preserved For Later Use By Adding Acid.
- The Prepupae Contain Other Potentially Valuable Components, Such As Chitin, In Recoverable Amounts.

Proximate and mineral analysis of dried black soldier fly prepupe

Dry Matter	93.9 %
NDF	24.7 %
ADF	2.2 %
Crude protein	47.3 %
Crude fat	30.6 %
Ca	4.74 %
P	0.77 %
Mg	0.38 %
Na	0.126 %
K	0.85 %
Fe	176 ppm
Cu	24 ppm
Zn	162 ppm
Mn	554 ppm

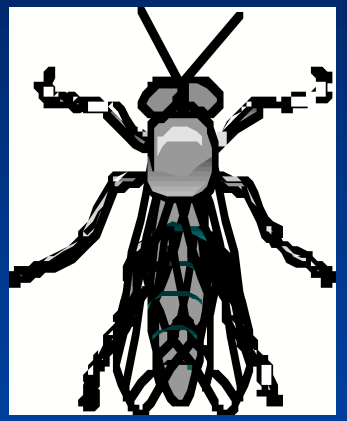
NDF = Neutral Detergent Fiber (chitin); ADF = Acid Detergent Fiber

Percent Amino Acid Content of Dried Soldier Fly Larvae

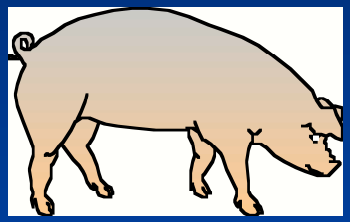
Essential Amino Acids		Additional Amino Acids	
Methionine	0.9	Tyrosine	2.5
Lysine	3.4	Aspartic acid	4.6
Leucine	3.5	Serine	0.1
Isoleucine	2.0	Glutamic acid	3.8
Histidine	1.9	Glycine	2.9
Phenylalanine	2.2	Alanine	3.7
Valine	3.4	Proline	3.3
Arginine	2.2	Cystine	0.1
Threonine	0.6	Ammonia	1.3
Tryptophan	0.2		

Use Of The Larval Feedstuff

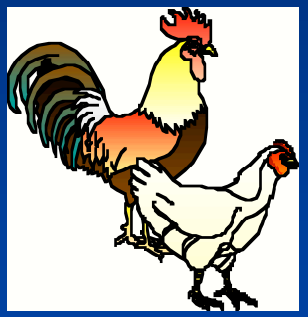
The Larval Feedstuff Has Been Successfully Included In Experimental Diets For:



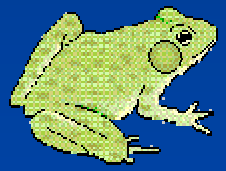
Pigs



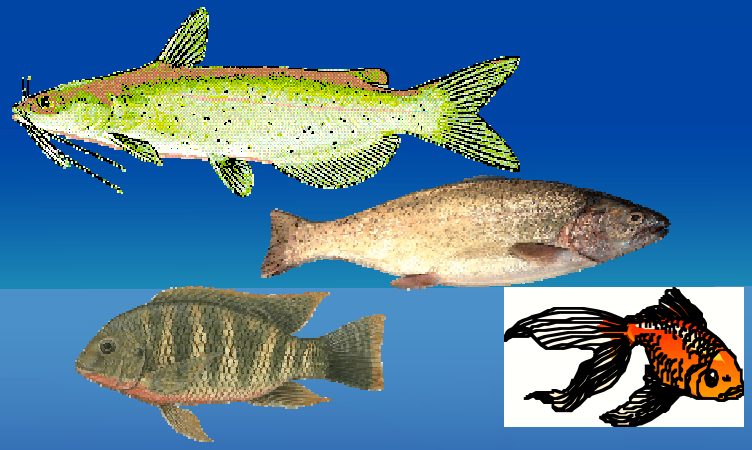
Chicks

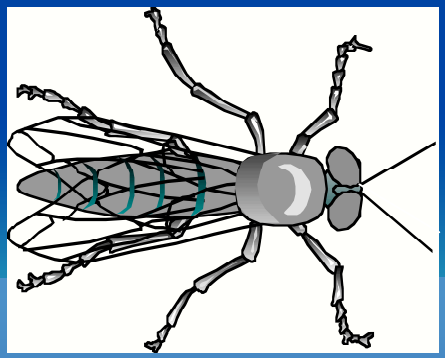


Frogs



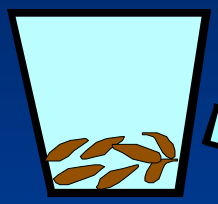
Fish
-Catfish
-Tilapia
-Trout
- Koi Carp





Utilization of Collected Prepupae

Can be fed directly to some animals, but likely will be processed.



Collected Prepupae (Last Larval Stage)

Processing

or

or

Drying

Rendering

Grinding or Chopping

Protein Meal

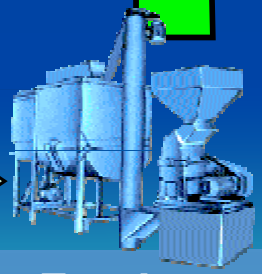
Oil

Other Potential Products (Chitin)

Other Potential Uses (Fuel Production)

Feed for Fish / Animals

Other Ingredients



Feed Preparation

Either or All

Feed Efficiency and Weight Gains of Channel Catfish Fingerlings Fed Black Soldier Fly Prepupal Supplemented Diets, and Comparison 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, $P<0.05$.

Fingerling channel catfish (4 aquaria per diet) were fed diets consisting of five rates of Hermetia prepupae substituted for menhaden fish meal in a base diet containing 8% fish meal. Fish weight gain and feed/gain were similar for diets 1 and 2, while both were superior ($P<0.05$) to all other diets for feed/gain, including the commercial fingerling feed.

From:
Gary Burtle, UGA

Soldier Fly Larvae Meal in Diets Balanced Without Fish Meal

Channel catfish (10 g) were fed experimental diets for 8 weeks. Levels of soybean meal, wheat middlings, corn, and soy oil were varied to make the diets similar in energy and protein. Growth, feed intake and feed conversion were similar (P<.05) for all five diets. Based on protein efficiency ratio, diets containing SF had a calculated average value of 108.5% of the diet containing 8% menhaden fish meal. From this study, not adverse performance was observed up to 30% addition of SF and 7.5% SF compared favorably to 8% menhaden fish meal.

Diet*	Inclusion Rate				
Soldier Fly Larvae Meal	0 %	7.5 %	15 %	22 %	30 %
Menhaden Fish Meal	8 %	0 %	0 %	0 %	0 %
Performance	**Average initial Weight, 10 g**				
Weight Gain of Fish**	15.9 g	18.0 g	17.3 g	13.7 g	15.9 g
Protein Gain	**With Fish Meal Set to 100**				
Protein Efficiency Ratio	100 %			108.5 %	

* Energy (DE, 2,934± 75 kcal/kg) and Protein (32.09± .09% CP) Balanced for All Diets

** No Significant Performance Differences (P<0.05)

From:
Gary Burtle, UGA

Feed Efficiency and Weight Gains of Rainbow Trout Fed Black Soldier Fly Prepupal Supplemented or Control Diets

Diet	1	2	3
*Replacement rate (%)	0	25	50
Feed/Gain	1.18 [a]	1.22 [a]	1.47 [b]
Gain/Fish (g)	136.9 [a]	121.0 [ab]	103.9 [b]

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

*Replacement of the fish meal component of the diet

Fish fed 50% prepupae had very low levels of omega-3 fatty acids.

Feeding soldier fly larvae, for a week or more, on media amended with fish offal, from a fish processer, had omega-3 concentrations similar to fish meal.

From:
Sophie St-Hilaire,
Idaho State

Why Feed to Fish?

- **Fish traditionally were fed diets with fish meal.**
- **During the early 1980's, fish meal prices were in the $200-300/ton range.**
- **Into the 1990's fish meal prices increased dramatically, by the late 90's prices were $400-600/ton.**
- **In the 2000's prices went to the $800's, and has increased another 50% within the past 2 years (currently $1200/ton).**
- **Fish feed production, while extensive, is more of a specialty market compared to livestock and poultry feeds making it easier to impact and penetrate.**

Two Photographic Views of Dense Black Soldier Fly Larval Populations Under Swine Pens.

Control Basins (Larvadex),
6-7 Inches Accumulation


Soldier Fly Basins,
1 1/2-2 Inches Accumulation

Summary

The black soldier fly (Hermetia) is a native, non-pest fly that is not attracted to human habitation or foods. Adults do not feed, live only a few days, and mate in aggregations at the edge of wooded areas. Female Hermetia deposit 500-1000 eggs near fresh perishable organics. Eggs hatch in 4 days and larva develop in 14-45 days, depending on temperature and nutrition.

Hermetia larvae can digest manure in basins under layer hens or swine, or collected organics or feces can be applied to basins. By providing a 35^0 ramp on the perimeter of the basin, non-feeding prepupal Hermetia, in search of pupation sites, leave the larval mass to fall into a collection device, thus self-collecting with no energy input or moving parts.

Summary

(continued)

Hermetia larvae reduce the dry mass of the wet waste about 50% while also excluding house fly infestation.

Several odorous compounds in head space above manure containing Hermetia larvae is reduced, and the population of potentially pathogenic microorganisms has been shown to be decreased in some cases.

The concentration of most nutrients and elements in manure residue from Hermetia culture is lower than in the media. The land area necessary to manage the remaining manure nutrients should be reduced 50-80%.

Summary
(continued)

Dried Hermetia prepupae have been shown to be a valuable feed ingredient for several animals. They are a source of animal protein and are high in energy, as they contain large quantities of oil.

The dried prepupae are expected to have an economic value between that of soybean meal and fish meal.

Remaining Problems; Will It Fly

The larvae require a warm environment to thrive and consume large amounts of media. A system for conserving metabolic larval heat, compatible with air flow, media introduction and prepupal self-harvest, is needed to allow for low-cost production during winter, and in cold climates.

Better systems for retrofitting existing animal facilities for Hermetia manure processing are needed. However, processing of organics, such as food waste or byproducts and ethanol production byproducts, delivered to a centralized processing facility, appears to be the near term opportunity.