Farm Scale Composting: Environmental Benefits, Challenges, and Economics

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OUTLINE

• Farm Scale Composting Systems
• Results from On-farm Dairy Manure Composting
• Economics of a Dairy Manure Composting System
• Environmental Benefits of Composting
  • Pathogen destruction (dairy+swine)
  • Antibiotic resistance gene destruction (beef+swine)
  • Nitrogen immobilization (dairy)
• Conclusions

Liquid Based Manure Management Systems

Lagoon Storage

Land application

Manure pack storage
Bedded Pack Systems

MANURE TREATMENT VIA COMPOSTING

- Compost amendments (sawdust, hay, straw, home bedding, recycled compost, etc.)
- Unseparated Manures
- Grow or Agitated Bed Composting
- Value Added Markets (Residential, Organic, Potting Media)

Free-stall barn
Manual or Automatic Scrape system,
Sand, Straw or Stall dust bedding

Separated Manure Composting and Reuse

Swine Manure Management
Deep Pit or High Rise Composting Systems

COMPOSTING

Gradients of Temperature
Oxygen, Moisture
Windrow Composting

Permeable Compost covers
Used to reduce water infiltration

Windrow Turners

Windrow Turners
Self propelled

Trench Systems

Trench systems with automatic turners
An agitated bed system used for dairy manure composting. Turners operate on the top of 8 ft high concrete walls. An inclined conveyor lifts and mixes the material, breaking preferential air pathways and moving the composting material along the channel. The turner moves the product 12 ft to 24 feet with each pass.

Source: Transform Compost

High-Rise Hog House with Aerated Floor for Composting/Drying

Hoop House System

Farm-Scale Windrow Composting of Swine Manure from a HRHB

Fresh Aire Farms, Ohio
RESEARCH OBJECTIVES

• Compare the effects of the two most commonly used compost amendments (hardwood sawdust and wheat straw) and the use of sand bedding on the decomposition rate and mass, volume, carbon and nitrogen losses during the composting of dairy manure.
• Develop design parameters for manure composting systems.
• Estimate costs for dairy manure compost systems.

Bedding Types used by Ohio Cows (% of cows)
- Sawdust 36%
- Sand 22%
- Straw 28%
- Other/Combo 14%

Treatments
1. Straw bedded dairy manure amended with sawdust
2. Straw bedded dairy manure amended with straw
3. Sand bedded dairy manure amended with sawdust
4. Four replicate windrows made in May, August, early September, late September.

Treatments
• Straw or sawdust amendments added to give an initial moisture content of approximately 65%
• Sand bedded manure amended with sawdust to give an ash free moisture content of 65% (51% wb).

Composting Process Design Measurements
• Temperature
• Oxygen Concentration
• Pathogen Survival
• Initial and Final Volume
• Initial and Final Weight
• Water loss
• Bulk Density and Porosity
• Nitrogen losses

Initial Compost Properties

<table>
<thead>
<tr>
<th>Compost ID</th>
<th>Moisture (% wet)</th>
<th>Total Carbon (%)</th>
<th>Total N (%)</th>
<th>C:N Ratio (g/g)</th>
<th>Bulk Density (wet kg/m³)</th>
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<tbody>
<tr>
<td>DM/Sawdust 1</td>
<td>65.5</td>
<td>46.4</td>
<td>1.4</td>
<td>32.9</td>
<td>380</td>
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<td>3</td>
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<td>67</td>
<td>44.7</td>
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<td>50.8</td>
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<td>2</td>
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<td>44.7</td>
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<td>42.7</td>
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<td>38.2</td>
<td>39</td>
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<tr>
<td>4</td>
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<td>44.2</td>
<td>1.2</td>
<td>37.0</td>
<td>173</td>
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<td>DM/Sand/SD 1</td>
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<td>36.1</td>
<td>0.7</td>
<td>54.0</td>
<td>411</td>
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<td>55</td>
<td>33.5</td>
<td>0.8</td>
<td>42.4</td>
<td>519</td>
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<td>61</td>
<td>31.8</td>
<td>0.8</td>
<td>38.5</td>
<td>590</td>
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<tr>
<td>4</td>
<td>65</td>
<td>28.5</td>
<td>1.1</td>
<td>26.5</td>
<td>711</td>
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</table>
Initial Windrow Manure Density
(kg manure per m of windrow length)
1. Sawdust amended dairy manure compost 1000 kg manure/m
2. Straw amended dairy manure compost 377 kg manure/m
3. Sand bedded dairy manure with sawdust 935 kg manure/m

Composting Temperatures

- Sawdust
- Straw
- Sand bedded + sawdust

Oxygen Concentrations during composting
Conclusions Part 1

- Dairy manure composting led to extensive reductions in manure volume and weight even after considering the weight of the added amendments.
- Sawdust amended windrows (with and without sand) contained 935 to 1000 kg manure/m while the straw amended windrows contained 377 kg manure/m, requiring a greater pad area.
- Sawdust amended composts without sand reached temperatures >55 °C in less than 10 days and met pathogen and weed seed destruction guidelines.
- Straw amended and sand bedded composts did not reach pathogen guidelines of >55°C for 15 days. Increasing windrow size may solve this problem.
- Moisture management was critical for manure weight reductions during composting. Once compost is stable, self-heating is not available to fuel evaporation of excess moisture.
- Sawdust amended composts without sand reached >55°C in less than 10 days and met pathogen and weed seed destruction guidelines.
- Moisture management was critical for manure weight reductions during composting. Once compost is stable, self-heating is not available to fuel evaporation of excess moisture.
- There was a negative correlation between initial C:N ratio and nitrogen loss (R=0.59). Therefore, to minimize nitrogen loss during dairy manure composting, a C:N ratio of 40:1 to 50:1 may be necessary.

<table>
<thead>
<tr>
<th>Compost Treatment</th>
<th>Amendment Costs ($/Mg)</th>
<th>Machinery Costs ($/Mg)</th>
<th>Labor Costs ($/Mg)</th>
<th>Total ($/Mg)</th>
<th>Sp (°C)</th>
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<tbody>
<tr>
<td>A</td>
<td>28.67</td>
<td>11.9</td>
<td>6.40</td>
<td>5.6</td>
<td>17.63</td>
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<td>B</td>
<td>28.47</td>
<td>0.02</td>
<td>2.87</td>
<td>0.91</td>
<td>17.89</td>
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<td>C</td>
<td>28.47</td>
<td>0.02</td>
<td>4.33</td>
<td>0.54</td>
<td>17.74</td>
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</tbody>
</table>

Table 4. Estimated production costs per Mg of cured compost (DM=Sawdust) compost produced with different turning frequencies and pile sizes.

Figure 6. Relative relationships between compost production and amendment costs for dairy manure composts sold for nutrient value (F, solid line), for $25/ yd³ (dashed line) or for $50/ yd³ (dotted line). Y-axis is the actual value of compost minus the estimated cost of production. Positive values indicate positive income for the compost producer.

Table 5. Nutrient concentrations, values and distance (mile) where transportation costs equal the nutrient value for liquid dairy manure composts (DM=S, produced in this study) and fertilizers (N15P15K).
Priority Pathogenic Bacteria
USDA

- **High Priority**
  - Enterohemorrhagic and related *E. coli* (DAIRY)
  - *Salmonella* spp. (DAIRY AND SWINE)
  - *Campylobacter*
  - *Listeria monocytogenes* (DAIRY AND SWINE)

- **Medium Priority**
  - *Yersinia enterocolitica*
  - *Clostridium perfringens*
  - other pathogenic *E. coli*

- **Low Priority**
  - *Mycobacterium av. Paratuberculosis* (Johne’s disease, Crohn’s disease, DAIRY)

Objective 1

Compare the persistence of *Salmonella* spp., *Listeria monocytogenes*, *E. coli* and *Mycobacterium avium paratuberculosis* (Johne’s disease), during the treatment of swine and dairy manure under conditions that simulate the most commonly used manure management methods.

Methods

1. Dairy Manure collected from a large farm previously shown to harbor *E. coli*, *Salmonella* and *Mycobacterium paratuberculosis*.
2. Swine Manure collected from the OARDC swine facility.
3. Manure mixed with sawdust, straw or water and added to triplicate reactors.
4. Dairy manure inoculated with 10⁵ CFU/g *Mycobacterium avium* subsp. *paratuberculosis*.
5. Swine manure inoculated with *Listeria monocytogenes* 10⁵ CFU/g and *Salmonella typhimurium* 10⁵ CFU/g.
6. Samples tested for *Salmonella*, *Listeria*, *E. coli* and *Mycobacterium avium paratuberculosis* using standard culture and MPN methods.
7. *Mycobacterium avium paratuberculosis* in dairy manure also assayed using an IS900 targeted PCR hybridization method.

Dairy Manure Treatment simulations

<table>
<thead>
<tr>
<th>Amendment</th>
<th>Incubation Temperature (°C)</th>
<th>Initial moisture content (%)</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sawdust</td>
<td>55</td>
<td>58</td>
<td>Composting</td>
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<tr>
<td>Sawdust</td>
<td>25</td>
<td>60</td>
<td>Manure pack</td>
</tr>
<tr>
<td>Straw</td>
<td>55</td>
<td>60</td>
<td>Composting</td>
</tr>
<tr>
<td>Straw</td>
<td>25</td>
<td>60</td>
<td>Manure pack</td>
</tr>
<tr>
<td>Water</td>
<td>20-25</td>
<td>85</td>
<td>Liquid storage</td>
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</tbody>
</table>

Swine manure treatment simulations

<table>
<thead>
<tr>
<th>Amendment</th>
<th>Incubation Temperature (°C)</th>
<th>Initial moisture content (%)</th>
<th>Simulation</th>
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</thead>
<tbody>
<tr>
<td>Sawdust</td>
<td>55</td>
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<td>Sawdust</td>
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<td>Water</td>
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<td>Aerated liquid</td>
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<tr>
<td>Water</td>
<td>20-25</td>
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<td>Liquid storage</td>
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Compost Reactor System Used for Pathogen Fate Studies
PROPERTIES OF THE DAIRY AND SWINE MANURE

<table>
<thead>
<tr>
<th>Sample</th>
<th>pH</th>
<th>Moisture Content (g/g wet)</th>
<th>Volatile Solids (g/g dry)</th>
<th>Total N (%) (TS basis)</th>
<th>Total N (%) (DW basis)</th>
<th>C/N ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Manure</td>
<td>8.0 ±0.1</td>
<td>72.9 ±11.4</td>
<td>25.9 ±1.4</td>
<td>1.4 ±0.2</td>
<td>14.4 ±1.1</td>
<td>10.5 ±0.4</td>
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<tr>
<td>Swine Manure</td>
<td>6.5 ±0.1</td>
<td>76.1 ±15.1</td>
<td>26.2 ±2.2</td>
<td>3.0 ±0.1</td>
<td>27.8 ±1.3</td>
<td>12.9 ±0.3</td>
</tr>
</tbody>
</table>

E. coli Persistence in Dairy Manure

detection limit = 11 MPN/gm

Listeria Persistence in Dairy Manure

detection limit = 11 MPN/gm

Salmonella Persistence in Dairy manure

detection limit = 11 MPN/gm
**Conclusions: Part 2**

- High temperature (55°C) composting of both dairy and swine manure was most effective in reducing priority pathogens.
  - After 3 days of dairy manure composting (55°C), naturally occurring *Escherichia coli*, *Salmonella*, and *Listeria* were not detectable.
  - In swine manure *Salmonella* and *Listeria* were reduced more than 3 logs after 3 days of composting (55°C) or aerated liquid treatment.
  - *Salmonella* and *Listeria* persisted for from 14 to 56 days in both swine and dairy manure during liquid storage.
  - *E. coli* and *M. avium paratuberculosis* persisted in dairy manure for 14 to 56 days during simulated lagoon treatment.
- Under all treatment conditions *Salmonella*, *E. coli* and *Listeria monocytogenes* reduced to low numbers after 56 days.
- Thermophilic composting is recommended for the treatment of manure destined for pathogen sensitive uses such as fruit or vegetable production, gardening or application to well drained fields.
• Composting addresses many unaccounted for negative impacts of liquid manure systems.
  – Pathogen destruction.
  – Antibiotic resistance genes destruction.
  – Nitrogen loss and odors.
  – Transportation effects on infrastructure

• Estimated dairy manure composting costs can be competitive with paying to haul manure off farm. Composting economics are positive when compost can be sold for greater than $20/yd³ and amendments are available at low costs.