Methane recovery and agronomic values of anaerobically digested solid beef cattle manure

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Cattle Production in Alberta

• Large confined operations produce a lot of manure
  o Applied to a relatively small land area
  o Nutrient loading creates large nutrient imbalances

• Alberta has 5.1 M cattle (42% of the national herd)
  o County of Lethbridge licensed feedlot capacity: ~900,000 head
  o Several feedlots >25,000 head

• Manure contains a lot of carbon, which may be converted to biogas (methane)

• Manure is not effectively used as fertilizer

• Poor manure management is an environmental issue
Manure Management Options

- Manure in feedlot pen
- Land application
- Stockpiling
- Anaerobic digestion
- Composting
Anaerobic Digestion as a Manure Management Option

• Anaerobic digestion is environmentally attractive
• Anaerobically digested manure, or “digestate,” is one of the final co-products of the biogas energy industry
• Digestates are typically good nutrient sources
The Knowledge Gap…

• Most research has been conducted on digestates from liquid swine manure and liquid dairy cattle manure

• Limited research conducted on solid manure

• Liquid and solid manure have different chemical and physical properties, so digestates from solid manure likely have different agronomic values than digestates from liquid manures
Objective

- To determine potential methane recovery and the agronomic values of anaerobically digested beef cattle manure
  - Barley forage yield
  - Forage barley N and P uptake
  - Apparent N and P recovery
  - Residual nitrate and soil test P levels
Methane Recovery from Beef Cattle Manure

- Measured by methane potential batch test for 40 days

- Methane recovery was:
  - 0.350 m$^3$ kg$^{-1}$ based on dry matter mass
  - 0.055 m$^3$ kg$^{-1}$ based on wet mass
Field Studies

Biogas plant location: Vegreville

Experimental sites: St. Albert and Lethbridge

Experimental periods: Four and five years

Experimental designs: Four amendments
    Two rates

Treatment list:
(1) Control (non-amended soil)
(2) Undigested manure
(3) Anaerobically digested manure (digestate)
(4) Separated solids of the digested manure
(5) Pelletized separated solids (St. Albert only)
Materials and Methods

Materials:

- Undigested cattle manure (33 to 50% solid)
- Digestate (4 to 9% solid)
- Separated solids (24 to 44% solid)
- Pellets (65 to 80% solid)
Materials and Methods

• Two rates (Assumed 50% total N available):
  – 1 × local recommended rate
  – 2 × local recommended rate

• Surface applied, double disk with minimal soil disturbance

• Seeded on same day or one day after amendment application
Amendment Application
## Amendment Properties

<table>
<thead>
<tr>
<th>Amendment†</th>
<th>WC§</th>
<th>pH</th>
<th>Total C</th>
<th>Total N</th>
<th>Org-N</th>
<th>Total P</th>
<th>NH₄-N</th>
<th>NO₃-N</th>
<th>C/Org-N</th>
<th>N/P</th>
<th>NH₄-N/Total N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestate</td>
<td>0.94 ± 0.01</td>
<td>8.1 ± 0.2</td>
<td>347 ± 25</td>
<td>70 ± 6</td>
<td>29 ± 4</td>
<td>9 ± 1</td>
<td>39 ± 6</td>
<td>21 ± 8</td>
<td>12 ± 1</td>
<td>8 ± 1</td>
<td>0.55 ± 0.05</td>
</tr>
<tr>
<td>Separated Solids</td>
<td>0.75 ± 0.01</td>
<td>8.5 ± 0.1</td>
<td>397 ± 37</td>
<td>17 ± 1</td>
<td>13 ± 1</td>
<td>5 ± 1</td>
<td>4 ± 1</td>
<td>14 ± 10</td>
<td>31 ± 4</td>
<td>3 ± 0</td>
<td>0.20 ± 0.07</td>
</tr>
<tr>
<td>Pellets</td>
<td>0.44 ± 0.08</td>
<td>8.3 ± 0.2</td>
<td>362 ± 32</td>
<td>18 ± 1</td>
<td>17 ± 1</td>
<td>5 ± 1</td>
<td>1 ± 0</td>
<td>1 ± 0</td>
<td>21 ± 2</td>
<td>4 ± 0</td>
<td>0.03 ± 0.01</td>
</tr>
<tr>
<td>Manure</td>
<td>0.62 ± 0.02</td>
<td>7.6 ± 0.4</td>
<td>388 ± 17</td>
<td>24 ± 2</td>
<td>20 ± 2</td>
<td>6 ± 1</td>
<td>4 ± 1</td>
<td>5 ± 1</td>
<td>20 ± 3</td>
<td>4 ± 0</td>
<td>0.17 ± 0.04</td>
</tr>
</tbody>
</table>

Values are means ± standard error
†All amendment properties are expressed on a dry mass basis
§WC is water content on a wet weight basis
Results: Barley Forage Yield

St. Albert

Lethbridge

Barley Forage Yield (Mg ha\(^{-1}\))

- Digestate
- Separated Solids
- Pellets
- Manure

St. Albert

Lethbridge

- Digestate
- Separated Solids
- Manure

P < 0.001
Results: Barley Forage N Uptake

St. Albert

Lethbridge

Barley Forage N Uptake (kg ha\(^{-1}\))

Digestate

Separated Solids

Pellets

Manure

Digestate

Separated Solids

Manure

\(P < 0.001\)
Results: Barley Forage P Uptake

**St. Albert**

- Digestate: a
- Separated Solids: b
- Pellets: b
- Manure: b

*P = 0.032*

**Lethbridge**

- Digestate
- Separated Solids
- Manure

*P = 0.594*
Results: Apparent N Recovery (Amended-soil N uptake / N applied)

St. Albert

Lethbridge

Apparent N Recovery (%)

Digestate Separated Solids Pellets Manure

Digestate Separated Solids Manure

P < 0.001

P < 0.001

Digestate Separated Solids Manure

Digestate Separated Solids Manure

0 5 10 15 20 25

0 5 10 15 20 25

a b c

a b

a b
Results: Apparent P Recovery (Amended-soil P uptake / P applied)

St. Albert

Lethbridge

$P = 0.385$

$P = 0.041$
Results: Amendment Derived N Uptake

(Amended-soil N uptake – Control soil N uptake) / Amended-soil N uptake
Results: Amendment Derived P Uptake

St. Albert

Lethbridge

\[ P = 0.055 \]

\[ P = 0.385 \]

(Amended-soil P uptake – Control soil P uptake) / Amended-soil P uptake
Barley forage yield (kg ha$^{-1}$ yr$^{-1}$)

Growing season precipitation (mm yr$^{-1}$)

Nitrogen uptake (kg ha$^{-1}$ yr$^{-1}$)

Phosphorus uptake (kg ha$^{-1}$ yr$^{-1}$)

$y = 52.34x + 1812$, $r = 0.96^{***}$, $n = 30$

Hao et al., 2016. Soil Science Society of America Journal
Summary

- Digestate led to 31 to 50% greater barley forage yield in St. Albert, and 24 to 26% greater yield in Lethbridge.

- At both sites, barley recovered two times more N from digestate than undigested cattle manure.

- Digestate led to greater barley forage P uptake in St. Albert.

Hao et al., 2016. Soil Science Society of America Journal
Thomas et al., Under Minor Revision, Agronomy Journal
Summary

• Pellets performed poorly, likely due to low surface area

• Separated solids performed similar to raw cattle manure

• On farm management strategies developed for raw cattle manure may be used for separated solids

Hao et al., 2016. *Soil Science Society of America Journal*

Thomas et al., Under Minor Revision, *Agronomy Journal*
Future Directions

• Improve nutrient recovery from pellets

➢ Why?

• Pelleting decreases the mass and volume of the separated solids, making transportation and land application more economical

• Pellets supply C and may act as useful slow release fertilizer
Acknowledgements

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