Can Carbonaceous Particle Amendments—including Biochar—Improve the Anaerobic Digestion of Agricultural Wastes?

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Anaerobic digestion can provide an environmentally sound approach to animal waste management.

Open-air, swine lagoons

Anaerobic digesters

Anaerobic digesters face startup, stability, and economic challenges.
Efficient electron transfer within anaerobic communities is critical for stable anaerobic digester operation.
Microbe-to-microbe electron transfer mechanisms

Mediated interspecies electron transfer (MIET)

Direct interspecies electron transfer (DIET)

DIET via pyrogenic carbonaceous material (PCM)

Our understanding of DIET is primarily limited to defined cultures

Defined cultures

- *Geobacter metallireducens* and *Methanosarcina barkeri*
- *Geobacter metallireducens* and *Methanosaeta harundinacea*

Objective: To determine the impact of PCM addition on the anaerobic digestion of animal wastewater

Swine wastewater properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total chemical oxygen demand (TCOD)</td>
<td>mg/L</td>
<td>4,800 ± 1,700</td>
</tr>
<tr>
<td>Total suspended solids (TSS)</td>
<td>mg/L</td>
<td>7,100 ± 600</td>
</tr>
<tr>
<td>Volatile suspended solids (VSS)</td>
<td>mg/L</td>
<td>4,700 ± 800</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>7.4 ± 0.2</td>
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</tbody>
</table>
# Particle properties

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Graphite</th>
<th>Biochar</th>
<th>AC</th>
</tr>
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<tbody>
<tr>
<td><strong>Conductivity</strong></td>
<td>S/cm</td>
<td>17 ± 2.6</td>
<td>0.22 ± 0.046</td>
<td>1.2 ± 0.25</td>
</tr>
<tr>
<td><strong>Surface area</strong></td>
<td>m²/g</td>
<td>0.6 - 19</td>
<td>15 - 209</td>
<td>258 – 1,596</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>mm</td>
<td>2.0 - 2.4 (granule), 0.21-0.25 (powder)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loading</strong></td>
<td>g particles /g VSS</td>
<td></td>
<td>6, 3, 1.5</td>
<td></td>
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</tbody>
</table>

### Controls
- Blanks (no particles)
- Glass particles

CH₄ generation rates were recorded in real-time to determine differences in bioreactor kinetics.

Sample cycle:
- Particle size: 212-250μm
- Loading rate: 6 g-particles/g-VSS
Graphite consistently resulted in higher normalized CH$_4$ production rates. Biochar & AC results depended on particle size.

![Graph showing CH$_4$ production rates](image)

- **Max. normalized CH$_4$ production rate**

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CH$_4$ recoveries followed a similar trend, except that all AC amendments decreased CH$_4$ recovery relative to the control.

Although CH$_4$ recoveries were lower with biochar and AC, more COD was removed than the no-particle controls.

COD removal in bioreactors and sterile bioreactors.

COD – chemical oxygen demand

COD likely adsorbed to biochar and AC, which reduced its conversion to CH$_4$

Fate of initial COD:

- **COD$_{CH_4}$**
- **TCOD$_{solids}$**
- **COD$_{VFAs}$**
- **TCOD$_{other}$**

There were no clear relationships between CH$_4$ production and PCM electrical conductivity.

Surface property structures varied across all particle types.

Graphite

Biochar

AC
Overall, only graphite consistently yielded larger normalized CH$_4$ generation rates and recoveries

- Biochar was not far behind graphite, with granular biochar yielding > 20% increase in CH$_4$ production rates than bioreactors without particles.
- Powdered biochar and AC amendments led to a sharp drop in CH$_4$ production rates
- Adsorption was the likely cause of high COD removals and low CH$_4$ recoveries for biochar and AC
- Economics
  - Graphite: $100 - $2,000 / ton  $3.36 / m^3$-wastewater
  - AC: $40 - $4,000 / ton  $1.34 / m^3$-wastewater
  - Biochar: $0.5 - $800 / ton  $0.02 / m^3$-wastewater
- We still need a better understanding of what exactly happens when biochar is added to digesters

Acknowledgements

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Collaborator: Dr. Francis de Los Reyes

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CH$_4$ volume (mL)

Time (d)

pH 7.2

pH 8.1
(A) Max. normalized CH\textsubscript{4} production rate vs. particle type and size.

- Granular
- Powdered

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(B) Max. normalized CH\textsubscript{4} production rate vs. surface area (m\textsuperscript{2}/g-VS\textsubscript{seed}).

- Graphite (R\textsuperscript{2}=0.73, p=0.019)
- Biochar (R\textsuperscript{2}=-0.10, p=0.51)
- AC (R\textsuperscript{2}=-0.25, p=0.89)
- Glass (R\textsuperscript{2}=-0.05, p=0.43)