A Preliminary Investigation of a Specific Methanogenic Activity Test for Quantified the Ammonia Inhibition of Anaerobic Digestion of Faecal Sludge Samples.

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Presentation plan

• Background context
• Methodology
• Results
• Discussion
• Conclusion
Biodegradation mechanisms

i : Fresh faeces
ii : Aerobic degradation of hydrolysable organic material
iii : Anaerobic digestion
iv : Mineralized sludge

VIP Latrines

Lack of knowledge on sludge anaerobic degradation kinetics

(Buckley, 2008)
Operating conditions

Optimized and controlled

Unplanned – uncontrolled

Simple sanitation systems

- a. Dry pit
  - Fly scree
  - Vent pipe
  - Concrete plate

Figure 2.15: Ventilated Pit latrine

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## Operating conditions

<table>
<thead>
<tr>
<th>Anaerobic digestion process</th>
<th>Pit latrine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature (°C)</strong></td>
<td></td>
</tr>
<tr>
<td>PR: 0-20 MR:20 - 45</td>
<td>15 – 30²</td>
</tr>
<tr>
<td>TR:50 - 65¹</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
</tr>
<tr>
<td>6,5 - 7,5¹</td>
<td>5,7 - 8,7³</td>
</tr>
<tr>
<td>Alkalinity (mg/L)</td>
<td></td>
</tr>
<tr>
<td>2 000 - 4 000</td>
<td></td>
</tr>
<tr>
<td>Inoculation</td>
<td></td>
</tr>
<tr>
<td>10% volume¹</td>
<td></td>
</tr>
<tr>
<td>Organic loading (g DCO/L)</td>
<td></td>
</tr>
<tr>
<td>&lt; 2</td>
<td>20 - 50⁴</td>
</tr>
<tr>
<td>N Inhibition (mg N_{TAN}/L)</td>
<td></td>
</tr>
<tr>
<td>1 700 - 14 000⁵</td>
<td>2 000 – 15 000³</td>
</tr>
<tr>
<td>VFA Inhibition (mg/L)</td>
<td></td>
</tr>
<tr>
<td>&gt; 3 000⁶</td>
<td>2 000</td>
</tr>
</tbody>
</table>


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**Specific methane activity tests (SMA)**

Ammonia inhibition can be adequately characterised and modelled by adapted specific methanogenic activity (SMA) tests.

<table>
<thead>
<tr>
<th>Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inoculum sources</strong></td>
<td>Anaerobic sludge</td>
</tr>
<tr>
<td><strong>Substrate</strong></td>
<td>Acetate</td>
</tr>
<tr>
<td><strong>Inoculum ratio (ISR)</strong></td>
<td>1.33 to 8 g SV / g COD</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>35 °C</td>
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<tr>
<td><strong>pH</strong></td>
<td>7</td>
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<tr>
<td><strong>Mixing</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Buffer</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Inhibitive substances</strong></td>
<td>NH₄Cl</td>
</tr>
</tbody>
</table>
SMA – Modelling of the bacterial growth curve

\[ \ln \left( \frac{N_0}{N} \right) \]

Gompertz

\[ y = A \exp \left\{ - \exp \left[ \frac{\mu m^e}{A} (\lambda - t) + 1 \right] \right\} \]

Methane production is growth associated

\[ \lambda \]  
\[ \mu_m \]  
\[ Time \]
**SMA – Modelling of methane production**

\[ y = A \exp \left\{ - \exp \left[ \frac{\mu_m e}{A} (\lambda - t) + 1 \right] \right\} \]

\[ M = P \cdot \exp \left[ - \exp \left( \frac{B \cdot R'}{P} (\gamma - t + 1) \right) \right] \]

- **M** : Cumulative CH\(_4\) production (ml)
- **P** : Maximum CH\(_4\) production (ml)
- **B** : VS (g)
- **γ** : Lag-phase (h)
- **S** : Substrat

**Sodium acetate**

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SMA of anaerobic sludge

$$y = A \exp\left\{ - \exp\left[ \frac{\mu_m e}{A} (\lambda - t) + 1 \right] \right\}$$

$$M = P \cdot \exp\left[ - \exp\left( \frac{B \cdot R' \cdot e}{P} (\gamma - t) + 1 \right) \right]$$
SMA of anaerobic sludge + acetate

\[ y = A \exp\left\{ - \exp\left( \frac{\mu_m e}{A} (\lambda - t) + 1 \right) \right\} \]

\[ M = P \cdot \exp\left[ - \exp\left( \frac{B R' e}{P} (\gamma - t) + 1 \right) \right] \]

- **M**: SMA (CH₄ ml/gVS)
- **P**: Methane potential
- **Time (h)**

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SMA of anaerobic sludge + acetate + NH$_4$Cl

$$y = A \exp\left\{- \exp\left[\frac{\mu_m e}{A} (\lambda - t) + 1\right]\right\}$$

$$M = P \cdot \exp\left[-\exp\left(\frac{B R^\prime e}{P} (\gamma - t) + 1\right)\right]$$
SMA inhibition of anaerobic sludge + acetate + increasing NH$_4$Cl

Ammonia concentration (mg TAN/L) vs. SMA (ml CH$_4$ / g VS*h$^{-1}$)
SMA – Experimental system – manometric

$\Delta \text{hPa}$
SMA – Feed materials

Fresh Faeces

Faecal sludge
SMA – Protocol

Homogenization

24h at 35 °C
Nitrogen flush

30 min at 35 °C
SMA – Protocol

Substrate injection

10 days at 35 °C
SMA – Protocol
SMA – experimental procedure

- FF or FS
- pH buffer
- pH 7

Parameters
- CH$_4$
- TS/VS
- COD
- pH

0 1.5g TAN/l 3g TAN/l 5g TAN/l 7.5g TAN/l 10g TAN/l
Blank

R’
**SMA of faecal sludge and fresh Faeces + acetate**

Methane production from faecal sludge and fresh faeces - ISR 4

<table>
<thead>
<tr>
<th>No Essai</th>
<th>Point</th>
<th>Vb</th>
<th>ISR</th>
<th>Inter</th>
<th>Reponse</th>
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<tbody>
<tr>
<td>1</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>36,1</td>
</tr>
<tr>
<td>2</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>33,9</td>
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<tr>
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<td>+</td>
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<td>36,2</td>
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<tr>
<td>4</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>32,7</td>
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</table>

Several plan experiments
## Characteristics of different sludge

<table>
<thead>
<tr>
<th>Parametres</th>
<th>Fecal sludge</th>
<th>Fresh feces</th>
<th>Anaerobic sludge</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.5 - 9.3</td>
<td>6.6</td>
<td>6.8 - 7</td>
<td>Kengne et al. (2011)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rose et al. (2015)</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>49,000</td>
<td>46 230 – 78</td>
<td>25 000</td>
<td>Rodríguez-Méndez (2015)</td>
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<tr>
<td></td>
<td></td>
<td>310</td>
<td></td>
<td>Chaggu (2004)</td>
</tr>
<tr>
<td>TAN (mg/L)</td>
<td>2 000 – 15 000</td>
<td>1 400</td>
<td>690</td>
<td>Rodríguez-Méndez (2015)</td>
</tr>
<tr>
<td>VS (% TS)</td>
<td>85</td>
<td></td>
<td>74</td>
<td>Rodríguez-Méndez (2015)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NWSC (2008)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rose et al (2015)</td>
</tr>
</tbody>
</table>
Conclusions

SMA tests using Gompertz model and specific substrate (acetate) has not lead to characterize the ammonia toxicity in anaerobic digestion of FF and FS.

Acetate doesn’t seem to be an appropriate substrate when performing SMA with FF or FS.

Testing the heterogenic methanogenic activity using different substrate.

(Buckley, 2008)
Thanks!