Ammonia removal: opening opportunities for new feedstocks and nutrient recycling

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Why strip ammonia from digesters?

- Ammonia becomes toxic when it reaches a high concentration
  - In mesophilic digesters > 4 g N L\(^{-1}\) causes problems
  - Acetoclastic methanogens more sensitive than hydrogenotrophic
  - Up to ~8 g N L\(^{-1}\), problems in mesophilic digesters can be alleviated using trace elements; but not in thermophilic conditions or with higher ammonia

- Removing ammonia could make it possible to run thermophilic digesters on food waste and other high N substrates

- It could be useful to recover ammonia
  - As a product: high-value fertiliser for crop use e.g. leaf spray
  - N removal balances the nutrient load in the digestate and increases the land capacity, especially in NVZs
Initial work

- Batch experiments to establish stripping parameters
  - Angeles de la Rubia using N\textsubscript{2} and other gases
  - Mark Walker using high VFA digestates before and after storage
  - Alba Serna Maza using fresh food waste digestates
  - Determine time constants for removal in different stripping conditions (pH, temperature)
Initial work

- Modelling of different process configurations
  - post-hydrolysis, *in situ*, side stream, post digestion
  - *In situ* appears attractive but requires very high gas flow rates (violent mixing)
Mesophilic trial

Work carried out by Alba Serna Maza
In practice

- Gas counter
- Motor
- Continuous stirred-tank reactors (mesophilic) 35-l volume
- Gas pump
- Ammonia stripping towers
- Heating mat
- Ammonia traps
- Temperature control
- Pump power supply
Phase 1 – establishing a baseline

- Initially all digesters operated at OLR 2 g VS L\(^{-1}\) day\(^{-1}\) for 1.1 HRT without stripping to establish baseline

**Specific biogas production**  
**TS and VS**  
**Total VFA**
Phase 2 – side-stream stripping

Baseline operation
Phase 2 – side-stream stripping

Stripping started on day 120

Control with no stripping

- 55 °C, pH 10
- 70 °C, pH N/C
- 70 °C, pH 10
Phase 2 – side-stream stripping

Day 250: gas stripping streams separated

Control with no stripping

85 °C, pH N/C

70 °C, pH N/C

70 °C, pH N/C, 2 towers

TAN (mg N kg⁻¹)

Time (days)
Phase 2 – side-stream stripping

- Day 300-380
- 85 °C, pH N/C
- 70 °C, pH 10 from day 328
- 70 °C, pH 10 from day 311, 2 towers

TAN (mg N kg\(^{-1}\))

Time (days)

- new food waste
- new tower conditions
- R1
- R2
- R3
- R4
## Overall stripping performance

<table>
<thead>
<tr>
<th>Temperature and pH</th>
<th>% TAN removal day $^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 °C pH 10</td>
<td>6.8</td>
</tr>
<tr>
<td>70 °C unadjusted pH</td>
<td>15.3</td>
</tr>
<tr>
<td>85 °C unadjusted pH</td>
<td>16.4</td>
</tr>
<tr>
<td>70 °C pH 10</td>
<td>20.6</td>
</tr>
<tr>
<td>85 °C unadjusted pH</td>
<td>30.0</td>
</tr>
</tbody>
</table>

TAN removal increase

Process requires high pH and high temperature
Performance

- Total VFA below 500 mg L\(^{-1}\)
- Good specific gas production - possible slight increase?
- TAN in digesters reduced by 46-70% → inhibition can be controlled
- No adverse effects on stability
Thermophilic stripping

- Same process configuration
- Natural TAN concentration toxic, so must maintain low concentrations from the start

- Inoculum from a mesophilic digester treating sewage sludge – adapted to thermo conditions
- Work carried out by Wei Zhang
Thermophilic stripping

All digesters same conditions: pH 10, 2.1 kg digestate stripped at 70 °C 2 x a week
Thermophilic stripping

Same pH, temp: quantity stripped in T1 & T2 increased to 2.5 kg twice a week
Thermophilic stripping

Stopped stripping in T4, doubled the amount stripped in T1 to 5 kg twice a week
Thermophilic stripping

Stopped stripping in T4, doubled the amount stripped in T1 to 5 kg twice a week
What are other people doing?

• Pedizzi et al. (2017) using air stripping rather than biogas
  – highly effective, no pH adjustment needed, but much larger volumes stripped (21% of digester volume 3 - 5 x a week)

• Bousek et al. (2016) looked at effect of different stripping gases
  – Flue gas might be more efficient than biogas

• Many others
What would we like to do next?

• Many aspects we can optimise
  – Type of gas and flow rate
  – pH control (in this study, Lime addition 14 g kg\(^{-1}\) digestate)
  – use of recovered ammonia (in this study 3.5 g N kg\(^{-1}\) digestate)
  – Continuous sidestream stripping
What does all this mean?

• Sidestream stripping shown to reduce TAN to low values → $\text{NH}_3$ inhibition can be controlled
  – makes digestion or co-digestion of high N feedstocks like slaughterhouse wastes a real possibility
  – makes thermophilic digestion an option for high N feedstocks

• TAN recovery as high value product possible, though economic feasibility may depend on scale

• Can control TAN concentration by modifying stripping conditions → ‘designer’ digestates possible to meet specific soil requirements

• Above all, we have a process that works and is ready for demonstration
Thank you!

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References


