Autoclaving as a pre-treatment for food waste

Charles Banks

Integration of Chemical, Biochemical and Thermal Processes

Joint ADNet/SUPERGEN Bioenergy Event
Priory Rooms, Birmingham, 6 Feb 2018
Background

• Work carried out as part of the FP7 VALORGAS project [www.valorgas.soton.ac.uk](http://www.valorgas.soton.ac.uk)

• Partners involved Aerothermal, Greenfinch,, Southampton (UK) and MTT Agrifood Research Finland
Aim

• Overall aim ‘To optimise pre-treatment of source segregated food waste for biogas production and biosecurity of the residual product’
• Autoclaving was one of a number of treatments tested, including pressurisation with CO$_2$, ammonia removal, two-phase digestion
Objectives

• To test at a relatively large scale to eliminate scale effects
• To use autoclave manufacturer’s recommended temperatures, retention times and operating mode
• To use real kerbside collected source segregated food waste
• To conduct the study in two independent locations
Waste

- Source segregated domestic FW was collected from the South Shropshire Biowaste digestion plant in Ludlow, UK
- Biodegradable bags used for waste collection were removed and the material was mixed and divided into 2 equal portions
Autoclaving

- One portion was pre-treated at 160 °C and 6.2 bars in a novel double-auger autoclave that provides improved mixing and steam penetration; the other portion was left untreated.

- Both portions were then passed through a macerating grinder.
Sending materials

• Packed into 35-L plastic boxes, frozen and shipped at -20 °C to MTT Agrifood Research, Finland (and arrived in winter)
  – 25 kg lots to comply with transfrontier shipment of waste regs

• Packed in 60-L blue drums, sent by courier to Greenfinch and frozen on arrival
### Properties of material received by MTT

<table>
<thead>
<tr>
<th></th>
<th>Control FW</th>
<th>Autoclaved FW</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.96 ± 0.16</td>
<td>5.01 ± 0.12</td>
</tr>
<tr>
<td>TS (g/kg)</td>
<td>247.5 ± 4.7</td>
<td>210.9 ± 18.6</td>
</tr>
<tr>
<td>VS (g/kg)</td>
<td>229.9 ± 4.5</td>
<td>194.6 ± 17.6</td>
</tr>
<tr>
<td>VS/TS (%)</td>
<td>92.9</td>
<td>92.3</td>
</tr>
<tr>
<td>SCOD (g/l)</td>
<td>98.2 ± 6.5</td>
<td>117.5 ± 10.3</td>
</tr>
<tr>
<td>TVFA (g/l)</td>
<td>3.1 ± 0.6</td>
<td>2.2 ± 0.2</td>
</tr>
<tr>
<td>TKN (g/kg)</td>
<td>7.4 ± 0.3</td>
<td>6.8 ± 0.3</td>
</tr>
<tr>
<td>NH₄-N (g/kg)</td>
<td>0.32 ± 0.12</td>
<td>0.41 ± 0.10</td>
</tr>
<tr>
<td>Fe (g/kg₁₅)</td>
<td>0.13 ± 0.01</td>
<td>22.73 ± 12.54</td>
</tr>
</tbody>
</table>
Experimental work at MTT

- 4 no. 11-L semi-continuous stirred tank reactors
- Mesophilic temperature
- Reactor experiments carried for over 450 days
  - OLR was gradually increased from 2 to 6 kg VS m\(^{-3}\) day\(^{-1}\)
  - HRT reduced from 117 to 39 days in control and from 94 to 31 days in autoclaved reactor
Experimental work at MTT

• BMP test results
Experimental work at MTT

- Specific methane production at different OLR
Experimental work at MTT

• TKN and TAN
Experimental work at MTT

- pH
Experimental work at MTT

• $\text{H}_2\text{S}$ – incomplete data

OLR to 4 kgVS/m3d
Biosecurity aspects

*FW Feed*
- In autoclaved FW all hygiene indicator organisms were < detection limit (5 cfu g\(^{-1}\))
- In the control FW *E. coli* was found together with Enterococci (3.72 x 10\(^3\) cfu g\(^{-1}\)) and Clostridia (3.82 x 10\(^4\) cfu g\(^{-1}\))

*Digestate*
- Total coliforms were below the detection limit in both digestates
- Clostridia found in concentrations of 1.63 x 10\(^2\) cfu g\(^{-1}\) in autoclaved FW reactor and 1.11 x 10\(^3\) cfu g\(^{-1}\) in control reactor
- Enterococcus quite high at around 10\(^8\) cfu g\(^{-1}\) in control and autoclaved digesters

*Conclusion*
Hygiene indicator concentrations in digestates were quite similar, but very different from the FW samples

Results suggests some survival from original inoculum, or other minor sources of contamination; conditions in the digesters are favourable for Enterococcus to proliferate
Summary of findings at MTT

Autoclaving of FW resulted in

• 5-10 % decrease in CH₄ yield
  – probably due to formation of refractory Maillard compounds from sugars and amino acids
  – these darken the colour and change odour of FW. Also change biodegradability making it harder or even impossible to degrade

• Lower TAN concentration (affects inhibition & fertiliser value)

• Lower pH due to decreased NH₄-N

• Lower H₂S production
  – due to reduced protein degradation

• Higher iron content in autoclaved digestate and lower pH also likely contributed to lower H₂S

• Autoclaving effective at hygienisation, but re-growth in digesters
Pilot-scale trials at Greenfinch

• 1 m³ pilot scale trials over 11 months
  – all tests carried out with the addition of trace elements

• Parallel operation with unautoclaved waste and with waste autoclaved at 160 °C
## Pilot trials – key results

- Specific methane production – weekly average

<table>
<thead>
<tr>
<th>Organic Loading Rate</th>
<th>Autoclaved digester</th>
<th>Non-autoclaved digester</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg VS m(^{-3}) day(^{-1})</td>
<td>m(^3) CH(_4) tonne(^{-1}) VS</td>
<td>m(^3) CH(_4) tonne(^{-1}) VS</td>
</tr>
<tr>
<td>2.3</td>
<td>359 (±36.2; n= 3)</td>
<td>500 (±98.9; n= 3)</td>
</tr>
<tr>
<td>3.7</td>
<td>426 (±76.6; n= 22)</td>
<td>485 (±15.3; n= 3)</td>
</tr>
<tr>
<td>4.0</td>
<td>430 (±13.6; n= 3)</td>
<td>453 (±4.2; n=3)</td>
</tr>
</tbody>
</table>
Pilot trials – key results

- TAN, pH, H\(_2\)S
Pilot trials – key results

Effects of autoclaving were

• A 5% reduction in methane yield at a loading rate below 4 kg VS m$^{-3}$ day$^{-1}$
• Significantly lower ammonia concentrations
• Lower VFA concentrations
• Significant reduction in H$_2$S concentrations
• Lower pathogen contents
Explanation of key results

• Some nitrogen and sulphur ‘locked up’ in denatured protein
• Some caramelisation of sugars
• Reaction of $\text{H}_2\text{S}$ with iron
Aerothermal studies on autoclaving

- Autoclaving at 160 °C, 140 °C, 120 °C
- Confirmed that at the two higher temperature there was a reduction in gas production, lower TAN and lower H$_2$S
- Further work at different temperatures carried out but not reported as part of the VALORGAS study
Conclusions from Aerothermal’s Autoclaving work

• As autoclaving at 140 - 160 °C allows stable digestion without requiring trace elements it would be particularly suitable for thermophilic digestion

• As it reduces ammonia and H\textsubscript{2}S levels it would be especially useful for problem feedstocks with high protein content including abattoir and food industry wastes

• As it can remove the need for mechanical de-packaging, shredding, maceration and pasteurisation, it would be particularly useful for poorly sorted and contaminated feed stocks
Valorisation of food waste to biogas
Project 241334

Sponsored by FP7 ENERGY.2009.3.2.2
Biowaste as feedstock for 2nd generation
Reference


Thank you