Food Waste Biomethanation In Farm-Scale Systems

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Organic fraction of MSW

- Up to 50% of the total waste generated
- Responsible for
  - leachates
  - Odor
  - Pest reproduction
  - Uncontrolled CO$_2$ & CH$_4$ releases
- Typical solid waste management methods as recycling and incineration cannot be used in this stream
- The problem is greater in touristic destinations due to seasonality and scarcity of available landfill sites
- The main form of organic municipal wastes is cooked and uncooked food
Source Reduction
Edible Food Rescue
Residential Backyard Composting
Small-scale, Decentralized Composting
Centralized Composting or Anaerobic Digestion
Mechanical Biological Mixed Waste Treatment
Landfill & Incinerator

Switch Off Eliminate waste - LEANER
Inhouse Waste Management - KEENER
Communal Waste Management - GREENER
Waste Valorisation - CLEANER
Offset to Compensate - MEANER
Anaerobic digestion

- Widely used as an animal manure treatment process due to the large volumes of wastewaters generated at farms

The objectives of this work was to investigate the thermophilic anaerobic digestion of the OfMSW together with CM, in large volume laboratory reactors (CSTR) with special attention given to the organic loading of the systems and the addition rate of the OfMSW into the digesters, furthermore the results used for an LCA analysis for the applicability of farm scale systems for treating these waste streams

-In order a system to be economically viable more than 18 m$^3$ of methane m$^3$ of wastes must be achieved. Co-digestion with other organic materials can be the solution to the low biogas yields in a win-win system
Material and methods

- OfMSW: collected from the main canteen of a university canteen.
  - The wastes were chopped in a bench top food grinder through a 3mm sieve and mixed in a ribbon blade mixer.

- CM: collected from a farm housing 50 dairy cattle
- Inoculum: acquired from anaerobic reactors (CSTR) operating under steady state
Characteristics of the substrates OFMSW

<table>
<thead>
<tr>
<th>Waste composition</th>
<th>OfMSW</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS (%)</td>
<td>33.9</td>
</tr>
<tr>
<td>VS (%TS)</td>
<td>94.9</td>
</tr>
<tr>
<td>TKN (g/kg)</td>
<td>7.43</td>
</tr>
<tr>
<td>pH</td>
<td>5.15</td>
</tr>
<tr>
<td>Lipids (%TS)</td>
<td>17.9</td>
</tr>
</tbody>
</table>

Characterized by low pH, high nitrogen and organic carbon, with great biodegradable content (VS/TS ~ 95%) and high total solid levels.
Cattle Manure (CM)

<table>
<thead>
<tr>
<th>Waste composition</th>
<th>Cattle Manure</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS (%)</td>
<td>6.73</td>
</tr>
<tr>
<td>VS (%TS)</td>
<td>84.7</td>
</tr>
<tr>
<td>TKN (g/kg)</td>
<td>1.40</td>
</tr>
<tr>
<td>pH</td>
<td>7.32</td>
</tr>
<tr>
<td>Lipids (%TS)</td>
<td>4.94</td>
</tr>
</tbody>
</table>

- Cattle manure has a nearly neutral pH, low total solid levels, balanced C/N ratio for biological treatment processes and a lower biodegradable content (VS/TS ~ 85%)
In the first experimental series, the substrates and substrate mixtures assessed in batches in VS in oc to VS subst of 1.5.

Three different mixtures were prepared from the same waste-wastewater with the addition of OM SW ranging between 10-30% by weight.

In the second phase of experiments, the three waste mixtures were assessed in 4 identical 50L stainless steel s-CST Reactors with the OLR of the systems to be governed by the TS and VS content of the produced waste mixtures with no dilution to be employed.

Methods

Digestion of the different substrate mixtures in batches

Digestion of the different substrate mixtures in 50 L anaerobic CSTRs

Process performance and methane recovery

Result analysis, viability & LCA analysis
<table>
<thead>
<tr>
<th>Mixture</th>
<th>OfMSW (% w/w)</th>
<th>CM (% w/w)</th>
<th>TS (%)</th>
<th>Average OLR VS (KgVS/m³-d)</th>
<th>pH</th>
<th>Feed based on VS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CM</td>
</tr>
<tr>
<td>1 (CM)</td>
<td>–</td>
<td>100</td>
<td>6.73 ± 0.2</td>
<td>2.71</td>
<td>7.32</td>
<td>100 0</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>90</td>
<td>9.87 ± 0.3</td>
<td>3.94</td>
<td>7.04</td>
<td>61.5 38.5</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>80</td>
<td>13.02 ± 0.2</td>
<td>5.52</td>
<td>6.57</td>
<td>41.5 58.5</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>70</td>
<td>15.68 ± 0.6</td>
<td>6.85</td>
<td>6.30</td>
<td>29.2 70.8</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>75</td>
<td>14.29 ± 0.3</td>
<td>6.19</td>
<td>6.49</td>
<td>34.7 65.3</td>
</tr>
</tbody>
</table>
Anaerobic digesters

Mixing and feeding tanks

Electronic controlling units and hot water recirculation bath
Results (batches)

OFMSW 30%  
OFMSW 20%  
OFMSW 10%  
CM 100%

Cumulative specific CH₄ production (mlCH₄/gVSadded)
LCA analysis scenarios

Scenario 1

Scenario 2 and 3
LCA analysis results
Centralized system

By applying the results obtained during the present study, the creation of a scenario for a TAD system based on a single 3.000 m³ CSTR which is treating CM with a daily influent stream of 140 m³ (HRT ~21-d) of wastes is possible.

• The daily output based on electric energy, 5.400 kWh of electric power (i.e. 1.200 €-d based on the 220 € per MWh feed-in tariff offered at the moment in Greece for digesters operating mostly on wastes (Greek Law N.3851/2010).

• by altering the feeding mixture with the introduction of 10, 20 and 25% OfMSW the daily output of the system will be:
  – 10.700 kWh (i.e. 2.350 €-d),
  – 19.700 kWh (i.e. 4.350 €-d) and
  – 23.200 kWh (i.e. 5.100 €-d) respectively,
Conclusion

• Thermophilic anaerobic digestion was shown to provide a tool for the treatment of mixtures of organic municipal wastes and cattle manures without the requirement of dilution or alterations on the hydraulic retention times of the digesters.

• No large scale inhibition phenomena on TAD systems were observed, even when mixtures of OfMSW and CM containing up to 65.3% OfMSW (based on VS) or 25% w/w were added into the process.

• OLRs as high as 6.2 kgVS/m³-d with the influent TS levels up to 14.3% can be accepted by CSTR systems, when the HRT is sustained to at least 21 days, without jeopardizing the process.

• Valorization of the OFMSW into established digesters is a safe, efficient and effective process and when possible it should be followed
Thank you for your kind attention

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A connectivity perspective to environmental health