10th International Conference on Sustainable Solid Waste Management
Chania, Greece

Effects of carbon-based materials on the anaerobic co-digestion of the organic fraction of municipal solid waste and thickened sludge: preliminary results

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22 June 2023
Effects of carbon-based materials on the AcoD of the OFMSW and TSL: preliminary results

Organic Fraction of Municipal Solid Waste (OFMSW)

- High Total Solids (TS, 15-30%)
- High Carbon to Nitrogen ratio (C/N)
- Nutrients’ (nitrogen, trace metals) deficiency
  - Low buffering capacity

Anaerobic co-digestion (AcoD)

Thickened Sludge (TSL)

- Low methane potential
- High water content (95-98%)
- Presence of (bio)recalcitrant and toxic compounds (heavy metals)

Biogas

Digestate

How can process’ performance be improved?
Mediated Interspecies Electron Transfer (MIET)

**ACIDOGENESIS**
- Fermentative bacteria
- VFAs
- Acetate
- Hydrogen
- Carbon dioxide

**ACETOGENESIS**
- Acetoclastic methanogens
- Hydrogenotrophic methanogens
- Methane
- Carbon dioxide

**METHANOGENESIS**
- VFAs
- Acetate
- Hydrogen
- Carbon dioxide
- Methane

**Fermentative**
- $H_2$
- $COOH^-$
- $CH_3COO^-$

**Hydrogenotrophic**
- $H_2$
- $CO_2$
- $CH_4$, $CO_2$

**Acetoclastic**
- $H_2$, $CO_2$
- $CH_3COO^-$
Direct Interspecies Electron Transfer (DIET)

1. Conductive pili ("nanowires")
   - Faster electron transfer
   - Higher reactions’ rates
   - More efficient conversion of intermediates (no VFAs’ accumulation)
   - Shortening lag phase → Increasing CH₄ yield

2. Cytochromes’ chain

(Wang & Lee, 2021)
4. Carbon-based materials

3. Iron corrosion

Fe$^0$ + 2H$_2$O $\rightarrow$ Fe$^{2+}$ + 2OH$^-$ + H$_2$

$3$Fe(OH)$_2$ $\rightarrow$ Fe$_3$O$_4$ + H$_2$ + 2H$_2$O magnetite
MATERIALS AND METHODS

**Prepared OFMSW**

<table>
<thead>
<tr>
<th>Fraction</th>
<th>% [w/w]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetable waste (lettuce)</td>
<td>30</td>
</tr>
<tr>
<td>Fruit waste (peels)</td>
<td>20</td>
</tr>
<tr>
<td>Potato waste</td>
<td>10</td>
</tr>
<tr>
<td>Meat waste (bovine meat)</td>
<td>12</td>
</tr>
<tr>
<td>Fish waste (stockfish skin)</td>
<td>5</td>
</tr>
<tr>
<td>Dairy waste (cheese crust)</td>
<td>3</td>
</tr>
<tr>
<td>Dry bread</td>
<td>8</td>
</tr>
<tr>
<td>Cooked rice</td>
<td>6</td>
</tr>
<tr>
<td>Cooked pasta</td>
<td>6</td>
</tr>
</tbody>
</table>

**Fraction**

- pH 6.1
- Total Solids (TS) 21.7%
- Volatile Solids (VS) 96.2% TS

**Fraction**

- pH 6.6
- Total Solids (TS) 2.2%
- Volatile Solids (VS) 78.9% TS
- Volatile Fatty Acids (VFAs) 226.4 mg/L
- FOS/TAC 0.54

**Granular Activated Carbon (GAC)**
- 10 g/L (1st-63rd day)
- 5 g/L (78th-105th day)

**Graphite (GR)**
- 10 g/L (1st-63rd day)
- 5 g/L (78th-105th day)

**Graphene Oxide (GO)**
- 0.2 g/L (1st-63rd day)
- 0.1 g/L (78th-105th day)

**Carbon Nanotubes (CNTs)**
- 0.2 g/L (1st-63rd day)
- 0.1 g/L (78th-105th day)

Dried at 35°C and shredded

**OFMSW**

\[ \frac{\text{VS}_{\text{OFMSW}}}{\text{VS}_{\text{TSL}}} [\%] \]

50/50

**OLR [g\text{VS}/L\cdot d]**

1.5

**HRT [d]**

21

**Graphene Oxide (GO)**
- 0.2 g/L (1st-63rd day)
- 0.1 g/L (78th-105th day)

**Carbon Nanotubes (CNTs)**
- 0.2 g/L (1st-63rd day)
- 0.1 g/L (78th-105th day)
**Effects of carbon-based materials on the AcoD of the OFMSW and TSL: preliminary results**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Reactor</th>
<th>C-based material</th>
<th>(\text{CH}_4) yield [NL/g VS]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D</td>
<td>GO</td>
<td>0.213</td>
</tr>
<tr>
<td>2</td>
<td>E</td>
<td>CNTs</td>
<td>0.207</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>GR</td>
<td>0.202</td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td>GAC</td>
<td>0.194</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>-</td>
<td>0.187</td>
</tr>
</tbody>
</table>

**Graph 1:**
- **I phase** (1st-63rd day)
- **II phase** (78th-105th day)

**Graph 2:**
- **I phase** (1st-63rd day)
- **II phase** (78th-105th day)

**Graph Notes:**
- **CNTs, GO**
  - similar behaviour
  - instant response of the system to virgin materials
  - shortened the start-up phase
- **GR**
  - good start then decrease with recover during no feeding period
- **GAC**
  - needs time to be colonised by bacteria
  - worst performance

**Legend:**
- A
- B
- C
- D
- E

**Graph 3:**
- CH\(_4\) yield [NL/g VS]
- Day

**Graph 4:**
- CH\(_4\) yield increase [%]
- Day

\* denotes statistical significance.
FURTHER INVESTIGATIONS

Microbial communities’ analyses

Investigating how maintaining CNTs and GO positive effects

Proving the economic convenience of the solution

Digestate quality analyses
Thank you for your attention

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22 June 2023