Biochemical methane potential applied to solid wastes - review

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Introduction

• Anaerobic digestion (AD) is a widely applied technology to treat solid wastes and produce biogas

• In Europe, exist around of 120 full-scale plants to AD municipal solid wastes.

Central Sewage Sludge Treatment Plant Bottrop
http://blogs.qub.ac.uk/atbest/page/2/

Introduction

- In Portugal (2013) biogas come from landfills (96 %), wastewater treatment plants and solid waste treatment plants

- Represent 1 % of the renewable sources
Introduction

How to increase the biogas production?

AD - optimization

Wastes from several sources or mixtures

BMP – Biochemical methane potential
most widely used technique

• To obtain the biodegradability of different substrates or mixture of substrates;
• To choose potential substrates to anaerobic digestion
Introduction

What is BMP test?

Substrates

Inoculum

Batch test
How to do BMP test?

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Inoculum</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>With or without pre-treatment</td>
<td>Source</td>
<td>Operational conditions</td>
</tr>
<tr>
<td></td>
<td>Amount</td>
<td>Gas measurement conditions</td>
</tr>
</tbody>
</table>

**Goal**

Present and evaluate the BMP factors, methodologies, solid organic substrates and results
BMP publications

How much interest exists for BMP?

• From 100 to almost 500

• Great amount of data biodegradability comparison from different solid wastes still problematic

• Publications between 2008 and 2015 - keywords “anaerobic digestion” and “BMP”

• Survey - Online Knowledge Library (B-on) with peer-reviewed publications.

*Results up until the end of April
BMP methods

• Owen et al. (1979) presents the most popular method for BMP in the last 3 decades. Still used with modifications (e.g. volume reactor, inoculum source and concentration);

• Chynoweth et al. (1993) analysed the influence of 3 factors: inoculum source, inoculum/substrate ratio (I/S) and particle size – inoculum active, I/S ≥ 2, particle size > 1 mm;

• Owens & Chynoweth (1993) also modified the Owen et al. (1979) methodology – substrate 2 g VS/L, medium with different mineral concentrations and inoculum (fed of 1.6 g VS/L), bottles 275 mL (100 mL of inoculum);
BMP methods

• Angelidaki and Ahring (1993) referred the need to acclimate the inoculum to specific conditions like the ammonia concentration;

• Angelidaki and Ahring (1997) - bottles of 117 mL with 20 mL of an adapted inoculum;

• Hansen et al. (2004) adapted and modified - bottles of 2 L (400 mL de inoculum and 100 mL of sample);
• Angelidaki and Sanders (2004) - a **substantial uncertainty in BMP** – AD is a complex process. Different units, e.g. L CH₄/kg-waste, L CH₄/L-waste, L CH₄/kg-VS added or L CH₄/kg-COD added (P = 1 atm and T = 0 °C);

• Angelidaki et al. (2009) - guidelines and advices for several factors - **substrate**, **inoculum source**, **inoculum activity**, **medium blank and controls**, **replicates**, **mixing**, **data collection**, **bottles volume** (0.1 to 2 L), **interpretation and reporting conditions**;

Factors affecting BMP tests

Gas Measurement Systems
- Volumetric methods
- Manometric methods
- GC

Experimental Conditions

Operational Conditions
- Physical
  - Reactor capacity
  - Temperature
  - Stirring
  - Incubation time
- Chemical
  - Headspace gas
  - pH and alkalinity
  - Mineral medium
- I/S ratio
BMP applied to solid substrates

- Approximately **70 different substrates** (around 80 references) submitted to BMP tests;

- **Solids** contents expressed in different units such as **g/L, g/kg, %, mg/L** and in **wet base**;

- **Total solids** (TS) contents represented in:
  - Percentage - 0.7 to almost 100 %;
  - g/kg units - 47.3 to 991 g/kg;
  - g/L - 3.97 to 331.33 g/L;

- **Volatile solids** (VS) contents presented in different bases, e.g. related with TS, dry mass and wet weight.
### BMP applied to solid substrates

#### Examples of solid substrates and solids contents

<table>
<thead>
<tr>
<th>Substrate</th>
<th>TS</th>
<th>VS</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewery grain waste</td>
<td>24.2 %</td>
<td>23.0 %</td>
<td>Kafle et al. 2013</td>
</tr>
<tr>
<td>Food waste</td>
<td>48,400 ± 2,700 mg/L</td>
<td>27,900 ± 1,300 mg/L</td>
<td>Elbeshbishy et al. 2012</td>
</tr>
<tr>
<td>Organic fraction of municipal solid waste</td>
<td>461 g/kg</td>
<td>386 g/kg</td>
<td>Nielfa et al. 2015</td>
</tr>
<tr>
<td>Two-phase olive mill solid waste</td>
<td>265 ± 3 g/kg</td>
<td>228 ± 2 g/kg</td>
<td>Rincón et al. 2016</td>
</tr>
<tr>
<td>Livestock residues on-farm</td>
<td>42-45 wt%, wet basis</td>
<td>31-35 wt%, wet basis</td>
<td>Yap et al. 2016</td>
</tr>
<tr>
<td>Secondary sewage sludge from WWTP</td>
<td>19.05 ± 1.21 g/L</td>
<td>13.99 ± 1.05 g/L</td>
<td>Abelleira-Pereira et al. 2015</td>
</tr>
</tbody>
</table>
BMP conditions and results

• Several items were analysed (2011 to 2016): inoculum and substrate sources, pre-treatment, reactor volume, headspace, I/S ratio, temperature, incubation time and measurement of biogas;

Examples of solid substrates and solids contents

<table>
<thead>
<tr>
<th>Reference</th>
<th>Inoculum source</th>
<th>Pre-treatment</th>
<th>Reactor (mL)</th>
<th>I/S</th>
<th>T (°C)</th>
<th>Incubation time (d)</th>
<th>Biogas Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples et al. 2011</td>
<td>Digested sludge</td>
<td>na</td>
<td>1,000</td>
<td>100 g/500 g</td>
<td>MC</td>
<td>21</td>
<td>25-456.3 mL CH₄/g ODM</td>
</tr>
<tr>
<td>Fernández-Cegrí et al. 2012</td>
<td>GS</td>
<td>Chemical and TC (75 °C)</td>
<td>250 (EV)</td>
<td>2 VS/2.5 COD</td>
<td>35</td>
<td>7-10</td>
<td>0-273 mL CH₄/gCOD&lt;sub&gt;added&lt;/sub&gt;</td>
</tr>
<tr>
<td>Ruggeri et al. 2015</td>
<td>CM</td>
<td>NaOH, Salts, US, US+salts</td>
<td>250</td>
<td>na</td>
<td>30</td>
<td>App. 60</td>
<td>2-193 L CH₄/kgVS₀</td>
</tr>
<tr>
<td>Naroznova et al. 2016</td>
<td>Collected from a WWTP</td>
<td>na</td>
<td>1,000</td>
<td>2 VS</td>
<td>37</td>
<td>45</td>
<td>202-572 mL CH₄/g VS&lt;sub&gt;substrate&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

na: not available
CM – Cattle manure; COD – Chemical oxygen demand; EV – Effective volume; GS – Granular sludge; MC – Mesophilic conditions; ODM – Organic dry matter; T – Temperature; TC – Thermochemical; US – Ultrasonic; VS – Volatile solids; WWTP – Wastewater treatment plant
## BMP experimental conditions and results

| Pre-treatments - thermal and chemical | Reactor volume - 60 to 3,000 mL | Incubation time - 7 to 216 d | Biogas - pressure transducer, volume displacement and syringe | Methane content - GC | Results of BMP tests - very discrepant and difficult to compare | Inoculum source - sludge from WWTP | I/S - 2 |

### Reactor Details:
- Reactor volume: 60 to 3,000 mL

### Incubation Details:
- Incubation time: 7 to 216 days

### Biogas Measurement:
- Biogas measurement methods: pressure transducer, volume displacement, and syringe

### Methane Content:
- Methane content analysis: GC

### Inoculum Source:
- Inoculum source: Sludge from WWTP

### Results:
- Results are very discrepant and difficult to compare.

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*Note: The table and diagram are intended to illustrate the experimental conditions and results of BMP testing.*
Conclusions

• **BMP continues to be widely used** to analyse the potential organic solid wastes

• Several attempts were made in recent years to **normalise the BMP tests**

• The variability of the substrate sources and its characteristics and the available resources imply **adaptation of several operational conditions tests**.

• BMP results, namely the **biogas or methane production** should be presented in comparable units.
Future Work

• Application of cheaper BMP methodologies and with less waste production;

• Continue the investigation concerning the availability of potential substrates for anaerobic digestion;

• Promote the waste management – more waste valorisation and less waste to landfill;

• More biogas production - energy resource applications.
Thank you for your attention

Questions?

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