Co-Digestion: Biogas Production & Digester Capacity Calculations
Agenda

- Biogas Potential
  - VS
  - COD
  - Carbohydrates, Lipids, Proteins

- Digester Capacity
  - Organic Loading Rate
  - Specific Energy Loading Rate
Co-Digestion Organic Material

- Fats: Solid at room temperature
  - Butter, shortening, margarine
  - Peanut butter
  - Meat trimmings
  - Uncooked poultry skin
  - Dairy: Cheeses, milk, cream, sour cream, ice cream
- Oils: Liquid at room temperature
  - Vegetable oil
  - Canola oil
  - Olive oil
  - Corn oil
  - Salad dressings
  - Cooking oils
- Grease: Turns to liquid during cooking, but solidifies when cooled
  - Gravy
  - Mayonnaise
  - Melted meat fat
  - Bacon and sausage
  - Boiled poultry skin
  - Salad dressing

Yogurt
Whey
Biogas Potential – VS

- **WEF MOP 8**
  - VSLR = 0.12-0.16 lb/d-cf (1.9-2.5 kg/m³-d)
  - Specific Digester Gas Yield = 13-18 cf/lb VSr (0.8-1.0 m³/kg VSr)
  - CH₄ fraction = 60-70%
  - Specific Methane Gas Yield = 7.8 – 12.6 cf / LB VSr (0.48 -0.7 m³/kg VSr)

### Digestion Time (d) VS destruction %

<table>
<thead>
<tr>
<th>Digestion Time (d)</th>
<th>VS destruction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>65.5</td>
</tr>
<tr>
<td>20</td>
<td>60.0</td>
</tr>
<tr>
<td>15</td>
<td>56.0</td>
</tr>
</tbody>
</table>

Biogas Potential – VS

How to do you get VS and VSr values for co-digestion organic materials?

How to do you get Specific Digester Gas Yield and Digester Methane Fraction for co-digestion organic materials?

• Lab Test – 550° muffle furnace
• Typically Empirical data
Biogas Potential – COD

\[
\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}
\]

2 moles of O\(_2\)/mole of CH\(_4\) = 2 \((32\text{g }\text{O}_2/\text{mole})/\text{mole }\text{CH}_4 \) = 64 g/mole CH\(_4\)

At standard conditions (0 deg and 1 atm) 1 mole CH\(_4\) = 22.414 L

\[
\frac{22.414 \text{ L}}{\text{mole } \text{CH}_4} \times \frac{\text{mole } \text{CH}_4}{64 \text{ g}} = \frac{0.35 \text{ L } \text{CH}_4}{\text{g COD}}
\]

Relationship holds for any type of anaerobically – digested material
Biogas Potential – COD

- **Specific Methane Gas Yield** = 5.61 cf/lb COD (0.35 L/g COD) at 0 deg C and 1 atm

  - Methane Energy Projection = 960 BTU/cf ft
  - Specific Energy Projection = 5,380 BTU/lb COD removed

\[
\frac{5,380 \text{ BTU}}{\text{lb COD}} \times \frac{\text{cf CH}_4}{960 \text{ BTU}} = \frac{5.61 \text{ cf CH}_4}{\text{lb COD}}
\]
Biogas Potential – COD

- Conventional Sludge 2:1 TPS/TWAS - 1.56 g COD/ g VSS
- Specific Methane Gas Yield = 5.61 cf/lb COD (0.35 L/g COD)

\[
\frac{1.56 \text{ g COD}}{\text{g VSS}} \times \frac{0.35 \text{ L CH}_4}{\text{g COD}} = \frac{0.546 \text{ L CH}_4}{\text{g VSS}} = \frac{0.546 \text{ m}^3 \text{ CH}_4}{\text{kg VSS}}
\]

WEF MOP 8 - Specific Methane Gas Yield = 0.48 - 0.7 m³/kg VSr
Biogas Potential – Carbohydrates, Protein, Lipids

- Digester Gas Methane Fraction (Symons and Buswell, & McCarty)

\[ C_nH_aO_bN_c + \left( n - \frac{a}{4} - \frac{b}{2} + \frac{7c}{4} \right) H_2O \rightarrow \left( \frac{n}{2} + \frac{a}{8} - \frac{b}{4} - \frac{3c}{8} \right) CH_4 + \left( \frac{n}{2} - \frac{a}{8} + \frac{b}{4} - \frac{5c}{8} \right) CO_2 + c NH_4HCO_3 \]

- Carbohydrates (C₆H₁₂O₆) = approx. 50% methane
- Proteins (C₄H₆.1O₁.2N) = approx. 42% methane
- Lipids (C₁₈H₃₆O₂) = approx. 72% methane
Biogas Potential – Carbohydrates, Protein, Lipids

- Digester Gas Methane Fraction (Symons and Buswell, & McCarty)

\[ C_nH_aO_bN_c + \left( n - \frac{a}{4} - \frac{b}{2} + \frac{7c}{4} \right) H_2O \rightarrow \left( \frac{n}{2} + \frac{a}{8} - \frac{b}{4} - \frac{3c}{8} \right) CH_4 \left( \frac{n}{2} - \frac{a}{8} + \frac{b}{4} - \frac{5c}{8} \right) CO_2 + c NH_4HCO_3 \]

- Doesn’t account for biomass yield or degradability

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Biomass Yield (g cells/g COD consumed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>0.35</td>
</tr>
<tr>
<td>Protein</td>
<td>0.20</td>
</tr>
<tr>
<td>Lipids</td>
<td>0.038</td>
</tr>
</tbody>
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Speece, R.E. (2008)
Co-Digestion Acclimation Period

David L. Parry (2013)
Digester Capacity - Organic Loading Rate

- **Organic Loading Rate**

  Mass of VS added per day per unit volume

  0.12-0.16 lb VS/d-cf (1.9-2.5 kg/m³-d)

Digester Capacity - Specific Energy Loading Rate

- SELR = energy loading/reactor biomass (gCOD/d per gVS in digester)

David L Parry (2013)
Example FOG – Loading Rate

David L. Parry (2013)
Questions from the Audience?


