Co – Digestion: Biogas Production & Digester Capacity Calculations

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Agenda

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

- Digester Capacity
  - Organic Loading Rate
  - Specific Energy Loading Rate

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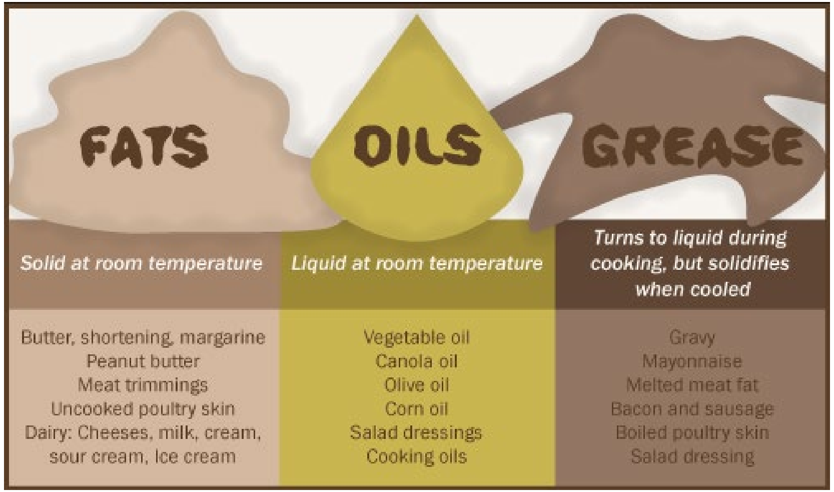
Co-Digestion Organic Material



Biogas Potential – VS

- WEF MOP 8
  - VSLR = 0.12-0.16 lb/d-cf (1.9-2.5 kg/m^3-d)
  - Specific Digester Gas Yield = 13-18 cf/lb VSr (0.8-1.0 m^3/kg VSr)
  - CH_4 fraction = 60-70%
  - Specific Methane Gas Yield = 7.8 – 12.6 cf / LB VSr (0.48 -0.7 m^3/kg VSr)

Digestion Time (d)	VS destruction %
30	65.5
20	60.0
15	56.0

Metcalf & Eddy 4th Edition (2003)

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

Waste Manag. 2010 Oct;30(10):1854-9. doi: 10.1016/j.wasman.2010.03.029. Epub 2010 Apr 18.

Anaerobic co-digestion of the organic fraction of municipal solid waste with FOG waste from a sewage treatment plant: recovering a wasted methane potential and enhancing the biogas yield.

Martín-González L[1], Colturato LF, Font X, Vicent T.

Author information

Abstract

Anaerobic digestion is applied widely to treat the source collected organic fraction of municipal solid wastes (SC-OFMSW). Lipid-rich wastes are a valuable substrate for anaerobic digestion due to their high theoretical methane potential. Nevertheless, although fat, oil and grease waste from sewage treatment plants (STP-FOGW) are commonly disposed of in landfill, European legislation is aimed at encouraging more effective forms of treatment. Co-digestion of the above wastes may enhance valorisation of STP-FOGW and lead to a higher biogas yield throughout the anaerobic digestion process. In the present study, STP-FOGW was evaluated as a co-substrate in wet anaerobic digestion of SC-OFMSW under mesophilic conditions (37 degrees C). Batch experiments carried out at different co-digestion ratios showed an improvement in methane production related to STP-FOGW addition. A 1:7 (VS/VS) STP-FOGW:SC-OFMSW feed ratio was selected for use in performing further lab-scale studies in a 5L continuous reactor. Biogas yield increased from 0.38+/-0.02 L g VS(feed)(-1) to 0.55+/-0.05 L g VS(feed)(-1) as a result of adding STP-FOGW to reactor feed. Both VS reduction values and biogas methane content were maintained and inhibition produced by long chain fatty acid (LCFA) accumulation was not observed. Recovery of a currently wasted methane potential from STP-FOGW was achieved in a co-digestion process with SC-OFMSW.

Biogas Potential – COD

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_20$$

2 moles of O_2/mole of CH_4 = 2 (32g O_2/mole)/mole CH_4 = 64 g/mole CH_4

At standard conditions (0 deg and 1 atm) 1 mole CH_4 = 22.414 L

$$\frac{22.414\ L}{mole\ CH_4} \times \frac{mole\ CH_4}{64\ g} = \frac{0.35\ L\ CH_4}{g\ COD}$$

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

$$\frac{5{,}380\ BTU}{lb\ COD} \times \frac{cf\ CH_4}{960\ BTU} = \frac{5.61\ cf\ CH_4}{lb\ COD}$$

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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)

$$\frac{1.56\ g\ COD}{g\ VSS} \times \frac{0.35\ L\ CH4}{g\ COD} = \frac{0.546\ L\ CH_4}{g\ VSS} = \frac{0.546\ m^3\ CH_4}{kg\ VSS}$$

WEF MOP 8 - Specific Methane Gas Yield = 0.48 - 0.7 m^3/kg VSr

Biogas Potential – Carbohydrates, Protein, Lipids

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

$$C_nH_aO_bN_c + \left(n - \frac{a}{4} - \frac{b}{2} + \frac{7c}{4}\right) H_2\text{O} \longrightarrow \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4} - \frac{3c}{8}\right) CH_4 + \left(\frac{n}{2} - \frac{a}{8} + \frac{b}{4} - \frac{5c}{8}\right) CO_2 + \text{c}\, NH_4HCO_3$$

- Carbohydrates ($C_6H_{12}O_6$) = approx. 50% methane
- Proteins ($C_4H_{6.1}O_{1.2}N$) = approx. 42% methane
- Lipids ($C_{18}H_{36}O_2$) = approx. 72% methane

Biogas Potential – Carbohydrates, Protein, Lipids

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

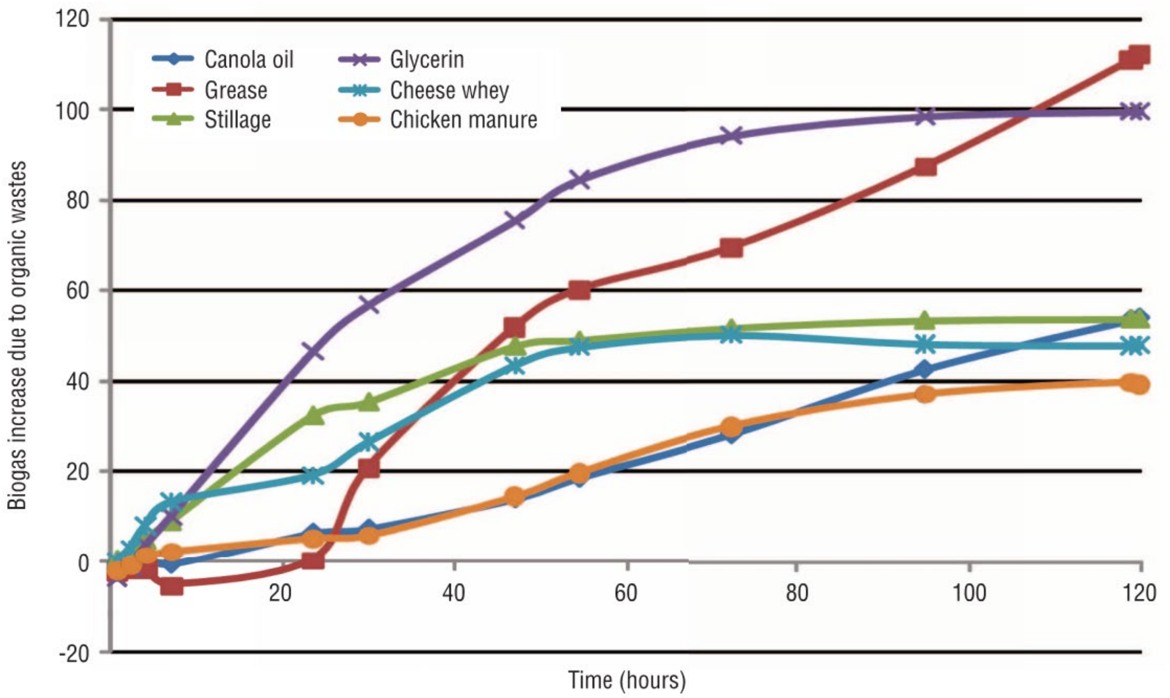
$$C_nH_aO_bN_c + \left(n - \frac{a}{4} - \frac{b}{2} + \frac{7c}{4}\right) H_2O \longrightarrow \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4} - \frac{3c}{8}\right) CH_4 \left(\frac{n}{2} - \frac{a}{8} + \frac{b}{4} - \frac{5c}{8}\right) CO_2 + c\, NH_4HCO_3$$

- Doesn't account for biomass yield or degradability

Substrate	Biomass Yield (g cells/g COD consumed)
Carbohydrates	0.35
Protein	0.20
Lipids	0.038

Speece, R.E. (2008)

Co-Digestion Acclimation Period



David L Parry (2013)

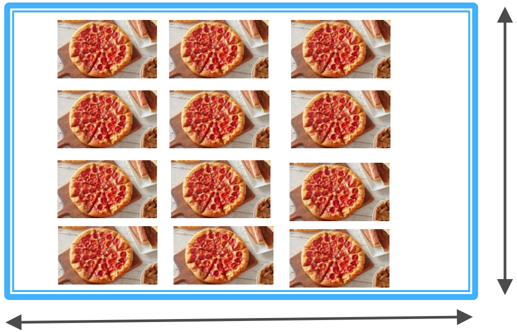
Digester Capacity - Organic Loading Rate

- Organic Loading Rate

Mass of VS added per day per unit volume

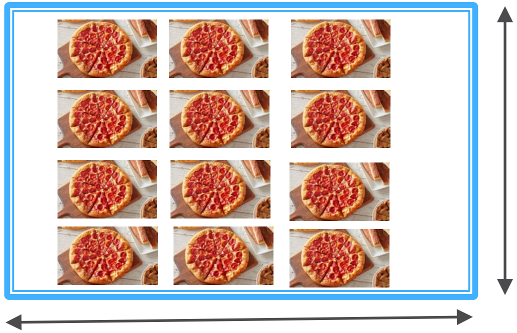
0.12-0.16 lb VS/d-cf (1.9-2.5 kg/m^3-d)

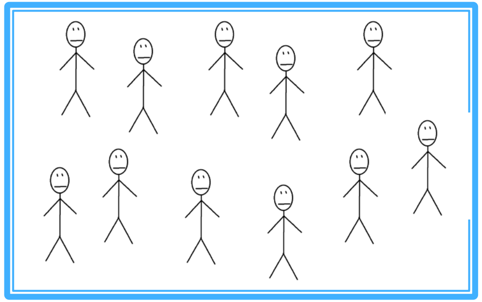
Metcalf & Eddy 4th Edition (2003)

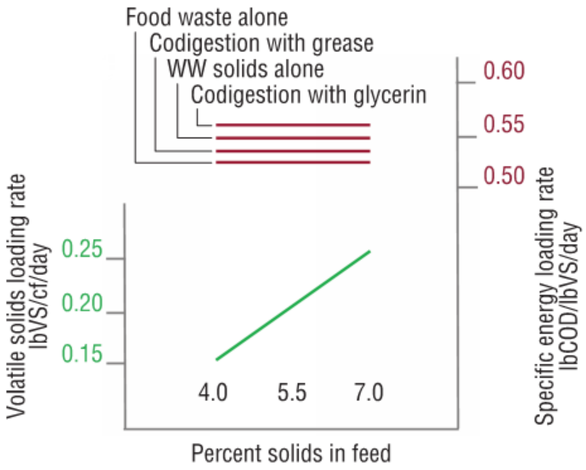


Digester Capacity - Specific Energy Loading Rate

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







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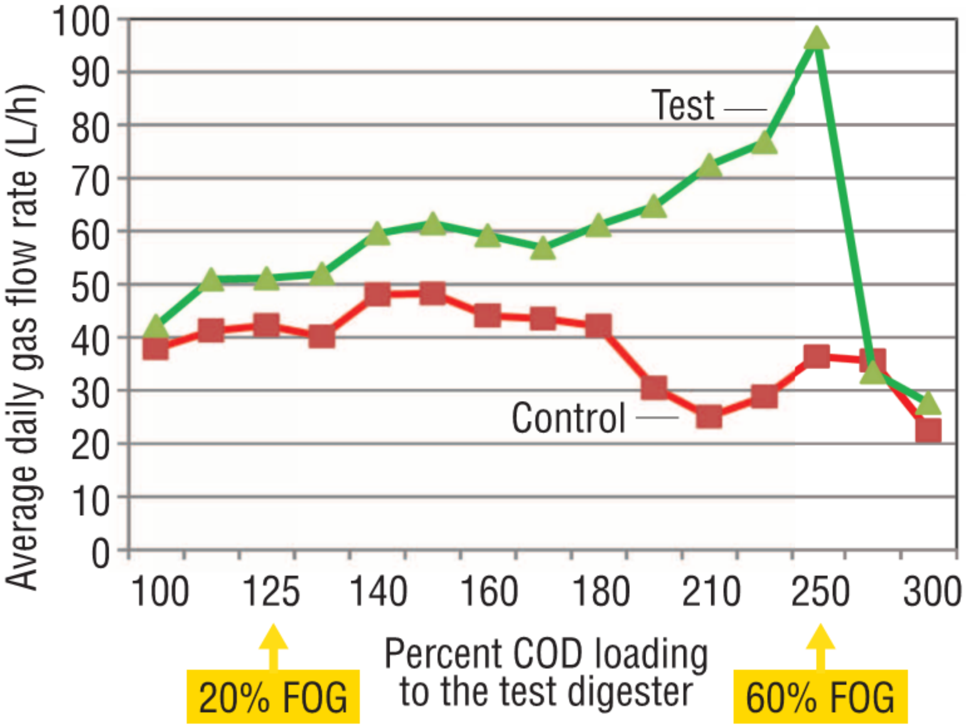
Example FOG – Loading Rate



David L Parry (2013)

Questions from the Audience?

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