Clarkson University Research Experiences on Food Digestion and Pathogen Fate

September 7th, 2016
3:30 PM-5:00 PM ET
Special Thanks

Moderator: Craig Frear, Regenis

Speakers:
- Dr. Stefan Grimberg, Clarkson University
- Dr. Shane Rogers, Clarkson University
Quick Notes

• You should be able to hear me talking now.
• Two Audio Options: Phone or Computer
  • Choose one and connect
  • Pro tip: Don’t call in on your phone if your audio is set to “Mic & Speakers”
• Ask questions using the Questions Panel on the right side of your screen ANYTIME.
• The recording of the webinar AND the slides will be available after the event. We will post them on uidp.org and send you a link.
American Biogas Council: The Voice of the US Biogas Industry

- The only U.S. organization representing the biogas and anaerobic digestion industry
- Over 200+ Organizations from the U.S., Germany, Italy, Canada, Sweden, Belgium and the UK
- All Industry Sectors Represented:
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  - equipment dealers
  - waste managers
  - waste water companies
  - farms
  - utilities
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  - Non-profits, universities and government agencies
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U.S. Biogas Market – Current and Potential

- **247** on Farm (Dairy AND Swine)
- **1,241** Wastewater (860 using their biogas)
- **645** at Landfills
- **2,100+** Operational Biogas Systems
- **8,241** on Farm (Dairy AND Swine)
- **2,400** Wastewater (incl. 381 making biogas but not using it)
- **11,000+** Potential Biogas Systems
- **440** at Landfills

American Biogas Council
Clarkson University Research Experiences on Food Digestion and Pathogen Fate

STEFAN GRIMBERG
SHANE ROGERS

CLARKSON UNIVERSITY
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
Clarkson University

- Clarkson University was founded in 1896
- Located in Potsdam, NY
- St. Lawrence County (more cows than people)
- Today has 4,300 undergraduate and graduate students majoring in 50+ degree programs
- Focus in engineering and science
  - CEE department has 400 undergraduate students, 18 faculty
  - Both Civil and Environmental Engineering programs are ranked highly in U.S. News & World Report Best Graduate Schools

Potsdam
Agenda

- Small digesters on College Campuses: Overcoming obstacles for a small scale, two-staged anaerobic digester system on a college campus
- Choosing a venue for land application of coproducts: What are the most important considerations?
- Clarkson University research on pathogen reduction in agricultural waste--how does anaerobic digestion perform?
Introduction

- 35 million tons of food waste is produced in US\textsuperscript{1}

- Landfills are third largest human methane source.\textsuperscript{1}

- High disposal costs of waste removal.

- Anaerobic digestion is a biological process that converts organic substrates into primarily methane and carbon dioxide in the absence of oxygen.

\textsuperscript{1} EPA, 2012, “Munical Solid Waste Report”
Why Digest Food Waste?

- Decrease GHG emission from organic waste in landfills.
- Extends lifetime of current landfills
- Reduce waste disposal cost
- Renewable energy source
- Valuable soil amendment
Food waste has higher biogas potential than other sources like agriculture and wastewater sludge.
Challenges

- High AD capital cost
- Variable low volume loading affect AD stability
- Few two stage AD using high strength waste
  - Acid fermentation – Methanogenic reactor
- Safe use of digested products as fertilizers
- Research goal:
  - Assess operation of a pilot scale two stage anaerobic digester of food waste
  - Determine an energy balance
Food Waste Success Stories

- **East Bay Municipal Utility District, Oakland, CA**
  - First wastewater treatment plant in the nation to convert post-consumer food scraps to energy via anaerobic digestion.
  - Methane powers plant and produces natural fertilizer.

- **Ralphs/Food4Less distribution center in Compton, CA**
  - Treating 150 tons/day
  - Offset more than 20 percent of the energy demand of the distribution center. Heat is captured from the microturbines for the digester process.
  - Separated solids are composted and sold, wastewater discharged to sewer.

- **University Wisconsin, Oshkosh**
  - Use dry fermentation technology to digest university food waste scraps and city yard waste to produce enough electricity to power up to 15% of institution’s electricity.
Ralphs/Food4Less distribution center in Compton, California showcases its 150 tons/day anaerobic digester

BioCycle June 2013, Vol. 54, No. 6, p. 41
University of Wisconsin - Oshkosh Biodigester
Oshkosh System

- **Dry AD technology**
  - High solids content (25% and above)
  - Material stays stationary within chamber
  - HRT = 28 days
  - No additional liquid input
  - Liquid is recirculated
  - Feedstock can be composted after AD

- **Power generation** 370 kW treating 8,000 tons of waste annually (22 ton/day)

  16.8 kW per ton of Feedstock
High solids Organic waste Recycling System with Electrical output
AD 25 Series Portable and Modular Bioenergy System
960 – 6,700 lbs. per week (440 – 3,050 kg per week) for
Food, Paper, Grass, Liquids Recycling

WWW.IMPACTBIOENERGY.COM
Clarkson’s System

- Vertical aeroponic greenhouse.
- Wood pellet and solar thermal collectors.
- Anaerobic digester for food waste.
Anaerobic Digester

- **Pre-consumer food waste**
  - 25-120 kg
  - 300 kg daily maximum
- **Three 1,400 gallon reactors with variable volume control**
  - Mesophilic Operation temperature
- **ENI 20kW co-generation combustion engine**
  - CHP
- **Instrumentation for independent operation and remote control**
Process of Anaerobic Digestion

Conventional single stage Digestion
Two Phase Digestion

1st Stage

Acetogenesis

Bio-gas (CH₄ & CO₂)

2nd Stage

Methanogenesis

Volatile Fatty Acid (VFA)

Hydrolysis

Influent

H₂ & CO₂

Effluent

Digested

Acidogenesis

Conventional single stage Digestion
Two Phase Digestion

Volatile Fatty Acid (VFA)
Clarkson’s Food Digester Operation

Food Waste

Grind

Blend

Dilution

Reactor 1

Reactor 2

Reactor 3

Effluent
Digester Heating Diagram

- Emax 20 kW Wood Pellet EnergyCabin, with solar thermal collectors
  - Plate heat exchanger
- 5kW Chromolox Electric Heater
- ENI 20kW CHP
Objectives and Tasks

- Objective:
  - Determine the effectiveness of a two-stage Anaerobic Digester system for food waste at a college campus with variable loading

- Tasks:
  - Energy Balance of system
Clarkson’s Mixed Food Waste Feedstock

- Chemical Oxygen Demand (COD): 295 ± 167 g/L
- Total Solids (TS): 24 ± 9%
- Volatile Solids (VS): 22 ± 9%
Food Loading Variation

Average 37 kg/day
Peaking Factor ~ 6
Chemical Characterization Results

93% Reduction in COD
94% Reduction in VS
Methane Production against COD removal

- Methane Yield: 488 L-CH$_4$·kg-COD$^{-1}$ removed (Range = 1784 – 15 L-CH$_4$·kg-COD$^{-1}$ removed)
Methane Production against VS Added

- Methane Yield: 628 L-CH$_4$·kg-VS$^{-1}$ Added (Range = 2230 – 13 L-CH$_4$·kg-VS$^{-1}$ added)
Energy Balance

- Biogas
- Tank 3
- Tank 2
- Tank 1
- Heat
- Co-Gen
- Electricity
Electricity consumption

- **Single Phase**
  - Lighting, Control Panels, Space Heaters, Valve Actuators, Sensors

- **Three Phase**
  - Pumps, 5kW electric heater, 5kW space heater, Blender

![Graph showing electricity consumption over time with two lines representing Single Phase and Three Phase, and one line representing Total (kWh). The graph indicates peak consumption during Summer and Winter.]
Heat Exchange from Energy Cabin

$\Delta T = 2.75$ Celsius

Temperature (°C)

Gas Production

- Biogas Production
- Methane Production

Days of Operation

Production (m³)
Energy Balance (Boiler)

50 kg/day food

- Energy (MJ)
  - Net Energy
  - Biogas
  - Electricity
  - Heat

- Days in Operation

- Energy Balance (Boiler)
  - Net Energy
  - Biogas
  - Electricity
  - Heat
Energy Balance (CHP)
Operational Capacity Energy Balance

300 kg/day food

Energy (MJ)

January  February  March  April  May  June  July  August  September  October  November  December

Heat Energy Demand  Excess Heat Energy (MJ)  Electricity Generation
Conclusions

- Boiler Operation at 50kg food/day, positive energy balance

- CHP at 50kg food/day, not enough heat to supply reactor demand

- CHP at 300 kg daily feeding shows positive energy balance
Beneficial Reuse
Beneficial Reuse:

Example: Clarkson Food Waste Anaerobic Digestion System

- Clarkson food waste digester effluents:
  - ~100 lb/d effluents in the summer
  - ~200 lb/d during the school year

- Characterization of effluents:
  - TS = 2.32%
  - VS = 1.33%
  - VS reduction = 94.2%
  - COD = 20.6 g/L
  - TAN = 5.54 g/L
  - TN = 8.07 g/L
  - Phosphate = 0.99 g/L
  - Potassium = 2.94 g/L
Considerations for Beneficial Reuse

- **Anaerobic digester feed material**
  - Pre-consumer / post-consumer food waste
  - Animal Byproducts (ABPs)
  - Import of wastes from other sites
  - Co-digestion
    - Wastewater treatment sludge
    - Animal manures or other farm residues
    - Energy crops

- **Digester size (quantity)**

- **Product quality**
  - Pathogens
  - Toxic metals
  - Stability
    - Residual biogas potential
    - VFA content
  - Nutrient contents and profile in effluents
  - Total and volatile solids

- **Location of use (onsite or offsite)**

- **Pre-treatment/Post treatment used**
  - Pasteurization
  - Composting
Beneficial Reuse: Microorganisms

- Microorganisms of potential concern in food wastes may include, among others:
  - Pathogens
    - Pre-consumer food waste:
      - Bacteria *e.g.*, *Salmonella* (var.), *Listeria monocytogenes*, shiga toxin-producing *Escherichia coli*, *Clostridium botulinum*, *Vibrio vulnificus*
    - Post-consumer food waste may increase variety of pathogens of concern
      - Viruses *e.g.*, *Adenovirus*, *Coxsakievirus*, *Hepatitis A virus*, *Herpesvirus suis*
    - Animal byproducts increase the variety and likelihood of pathogens of concern – see *PAS110 (2014)*
    - Co-digestion with sewage sludge significantly increases pathogen risks – *Biosolids regulations will need to be considered (40 CFR Part 503)*
    - Co-digestion with livestock manure: significantly increases potential for zoonotic pathogens as well as pathogens of concern for livestock animals (*e.g.*, mastitis pathogens where organic solids are reused as bedding for dairy cows)
  - Spoilage organisms
    - Bacteria *e.g.*, *Clostridium perfringens*, *Pseudomonas* spp., *Acinetobacter* spp., *Moraxella* spp.
    - Yeasts *e.g.*, *Brettanomyces bruxellensis*, *Debyomyces hansenii*, *Zygosaccharomyces rouxii*
    - Molds *e.g.*, *Botrytis cinerea*, *Penicillium*, *Aspergillus*, *Geotrichum candidum*
Beneficial Reuse: Microorganisms

- Requisite product quality depends on how digester products are reused
  - May need to be pathogen-free for use on
    - Food crops
    - Lands frequented by people

>9 million illnesses each year are caused by consumption of food tainted by pathogens of known etiology, and an additional 38.4 million by pathogens of unknown etiology.
Beneficial Reuse: Microorganisms

- Requisite product quality depends on how digester products are reused
  - May need to be pathogen-free for use on
    - Food crops
    - Lands frequented by people
  - Problems may extend beyond fertilization areas
    - Runoff
Beneficial Reuse: Microorganisms

- Requisite product quality depends on how digester products are reused
  - May need to be pathogen-free for use on
    - Food crops
    - Lands frequented by people
  - Problems may extend beyond fertilization areas
    - Runoff
    - Aerosols and odors

Recommended minimum setback distance of 160-m based on 1:10,000 acceptable median risk
Beneficial Reuse: Quality recommendations

- **PAS 110:2014** Specification for whole digestate, separated liquor and separated fibre derived from the anaerobic digestion of source-segregated biodegradable materials – British Standards Institution

- **Non-ABP digestate:**
  - *E. coli* < 1,000 CFU / g fresh matter
  - *Salmonella* spp. absent in 25 g fresh matter
  - Typically achieved through pasteurization prior to anaerobic digestion

- **Product Stability:** < 0.45 L biogas / g volatile solids

- **Toxic elements:**

<table>
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<tr>
<th>Element</th>
<th>mg/kg</th>
<th>Less than 1</th>
<th>1 to 1.9</th>
<th>2.0 to 2.9</th>
<th>3.0 to 3.9</th>
<th>4.0 to 4.9</th>
<th>5.0 to 5.9</th>
<th>6.0 to 6.9</th>
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<td>0.24</td>
<td>0.36</td>
<td>0.48</td>
<td>0.60</td>
<td>0.72</td>
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<td>80</td>
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<td>128</td>
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<tr>
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<td>0.32</td>
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<td>Lead (Pb)</td>
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</table>

- Declare the following characteristics as typical or actual:
  - pH
  - Total Nitrogen
  - Total Phosphorus
  - Total Potassium
  - Ammonium Nitrogen (KCl extractable)
  - Total solids (dry matter)
  - Volatile solids (loss on ignition)
Beneficial Reuse: Quality recommendations

Additional considerations for co-digestion with sewage sludge:

- **40 CFR Part 503**: Specification for Class A biosolids from sewage sludge – US EPA
- **Pathogens**:
  - Fecal coliform bacteria < 1,000 MPN / g dry total solids, or
  - Salmonella spp. < 3 MPN / 4g dry total solids, and
  - Process to Further Reduce pathogens (1 of 6 recommended, or permitted equivalent)
- **Product Stability**:
  - >40% reduction in volatile solids
  - Use of 1 of 10 options for vector attraction reduction, or permitted equivalent
- **Toxic elements**:
  - Based on product quality (pollutant ceiling and exceptional quality concentrations)
  - Based on loading rate to receiving land (annual and cumulative pollutant loading rates)
  - Effectively, need to achieve exceptional quality criterion
Beneficial Reuse: Quality recommendations

Additional considerations for co-digestion with manure:

- **Pathogens:**
  - No additional (regulated) pathogen reduction requirements
  - Consider the intended re-use scheme and potential disease pathways
    - On-farm vs. off-farm use
    - Livestock pathogens (e.g., mastitis pathogens if reuse as bedding)
  - Dairy farm, Northern New York, 1-stage mesophilic AD, dairy manure only:
    - 1.6-2.1 log reduction
  - Potsdam Wastewater Treatment Plant, Northern New York, 2-Stage mesophilic AD, sewage waste only:
    - Stage 1 = 1.3 – 2.6 log reduction
    - Stage 2 = 1.8 – 2.1 log reduction

### Table

<table>
<thead>
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<th>Bacteria</th>
<th>Farm Digester</th>
<th>Wastewater Treatment Plant Digester</th>
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<tr>
<td></td>
<td>%</td>
<td>Log</td>
<td>%</td>
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<td>Fecal Bacteroidales</td>
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<tr>
<td>Pathogens</td>
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<tr>
<td>Enterococcus spp.</td>
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<td></td>
<td></td>
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</tbody>
</table>
Beneficial Reuse:

Example – Small Farm Anaerobic co-digestion system

Example small-scale system for co-digestion with manure:

- Pilot-scale small farm digester with co-digestion recirculator for food waste, waste grass, waste feed, and waste silage

- USDA-funded project in collaboration with Cornell Cooperative Extension Services of St. Lawrence County

Manure feed system

Anaerobic digestion and effluent

Food waste recirculator
Beneficial Reuse:  
*Example* – Small Farm Anaerobic co-digestion system

- **Research – Education – Outreach effort**
- Co-digestion with high energy wastes improve biogas stabilization, nutrient balance and digestion performance

**Manure**
- Low C/N ratio – high ammonia
- High alkalinity
- Rich in macro/micro nutrients

**Crop or Crop residues**
- High C/N ratio – high carbon content
- Low alkalinity
- Lack of macro/micro nutrients

Improve the C/N ratio, buffering capacity and more biodegradable substrate

**Ongoing / future efforts:**
- Sustainable (small-scale) pathogen reduction towards beneficial reuse of digester effluents for food crop production
- Small-scale solids separation for digester influent
- Integration of heating loop into adjacent greenhouse facility to enable earlier seed germination for food crops
- Extended education and outreach to farmers including demonstration for sand bedding separation and recycle based on prior efforts
Beneficial Reuse: Conclusions and Recommendations

- Beneficial reuse is very achievable
- Final disposition (use onsite or off-site, use as fertilizer or other, fertilization of food crops or non-food crops, etc.) and final product quality should be considered together
- Reuse often hinges on pathogen reduction, which can be a challenge at the small-scale
- Further work is needed to quantify pathogen reduction in small food waste systems co-digestion systems and effective control measures to maximize reuse potential
Acknowledgements

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  - U.S. Environmental Protection Agency
  - United States Department of Agriculture
  - Clarkson Sustainability Fund
  - NYS Pollution Prevention Institute
**Q&A**

Ask questions using the *Questions Panel* on the right side of your screen.

All questions and comments will be recorded.

A recording of the webinar and slides will be available by Thursday, September 8th to all ABC Members and all attendees of the webinar.
Join us for our next webinar!

“Enzyme Technology to Drive Profits in Biogas Production”

Speaker: Dr. Jaclyn DeMartini, DuPont Industrial BioSciences

September 28th, 2016
3:30-5:00 PM ET

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Thank you!

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