Anaerobic Digesters as Renewable Energy Facilities

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Anaerobic Co-Digestion

- The microbiological production of methane with mixtures of various wastes from different locations or sources.

- Mixing of wastes can result in both synergistic and antagonistic interactions

Co-Digestion

Advantages

- Improved nutrient balance
- Equalization of floating, settling, acidifying wastes through dilution
- Additional biogas production
- Economical use of existing equipment
- Potential greenhouse gas emissions reductions accrued

Co-Digestion

Disadvantages

- Can be more complicated system
- Conveyance costs can be high
- User fee structure can be difficult to determine
- Transport/handling liability
- Codigestate pretreatment equipment and operating costs

Anaerobic Digesters as Renewable Energy Co-Digestion Facilities

- If handled through landfills and sewers, wastes are not used as feedstocks to produce renewable energy.
- Industrial and municipal wastewater treatment plants have anaerobic treatment systems.
- Systems could potentially be used to co-digest other high-strength wastes to produce more methane.
- In this way, existing anaerobic systems and equipment can be used to become renewable energy facilities.

Co-Digestion in the US

- Waste aircraft deicing fluid
  - Milwaukee Metropolitan Sewerage District, Milwaukee, WI (2001 - present)

- Food waste
  - Inland Empire Utilities Agency, Chino, CA
  - East Bay Municipal Utilities District, Oakland, CA
  - Department of Public Works - LA Airport, Los Angeles, CA

Co-Digestion in the US

- Fat, oil and grease
  - East Bay Municipal Utilities District, Oakland, CA
  - Public Works Department, City of Riverside, CA

- Agricultural, food and other wastes
    - Developed by Microgy, Inc., Golden Colorado
      - Five Star Dairy, Elk Mound, WI
      - Joseph Gallo Farms - Columbard Dairy, Atwater, CA
      - Huckabay Ridge (Dairy/Cheese), Stephenville, TX

    - Others?
- Other co-digestates?

Milwaukee High-Strength Wastes Tested

- Miller Brewing Company beer filter waste
  - COD = 3,000 - 6,000 mg/L
- Lasaffre Yeast Corporation, first pass beer waste
  - COD = 40,000 - 60,000 mg/L
- Southeastern Wisconsin Products, yeast flavoring production waste
  - COD = 80,000 - 90,000 mg/L
- General Mitchell International Airport waste deicing fluid
  - COD =100,000 - 200,000 mg/L
- Restaurant food waste
  - COD = 200,000 - 500,000 mg/L

Food Waste Disposal Background Information

- Much food waste is currently disposed of in landfills.

- Estimated 663,860 tons of food waste disposed of in Wisconsin landfills in 2000
  - Food waste is 18% of total solid waste produced in the state
  - Total MSW increasing approximately 40 tons/year
  - 60% of food waste from residential/ 40% non-residential

- Food waste takes up landfill space and leads to potential groundwater pollution.

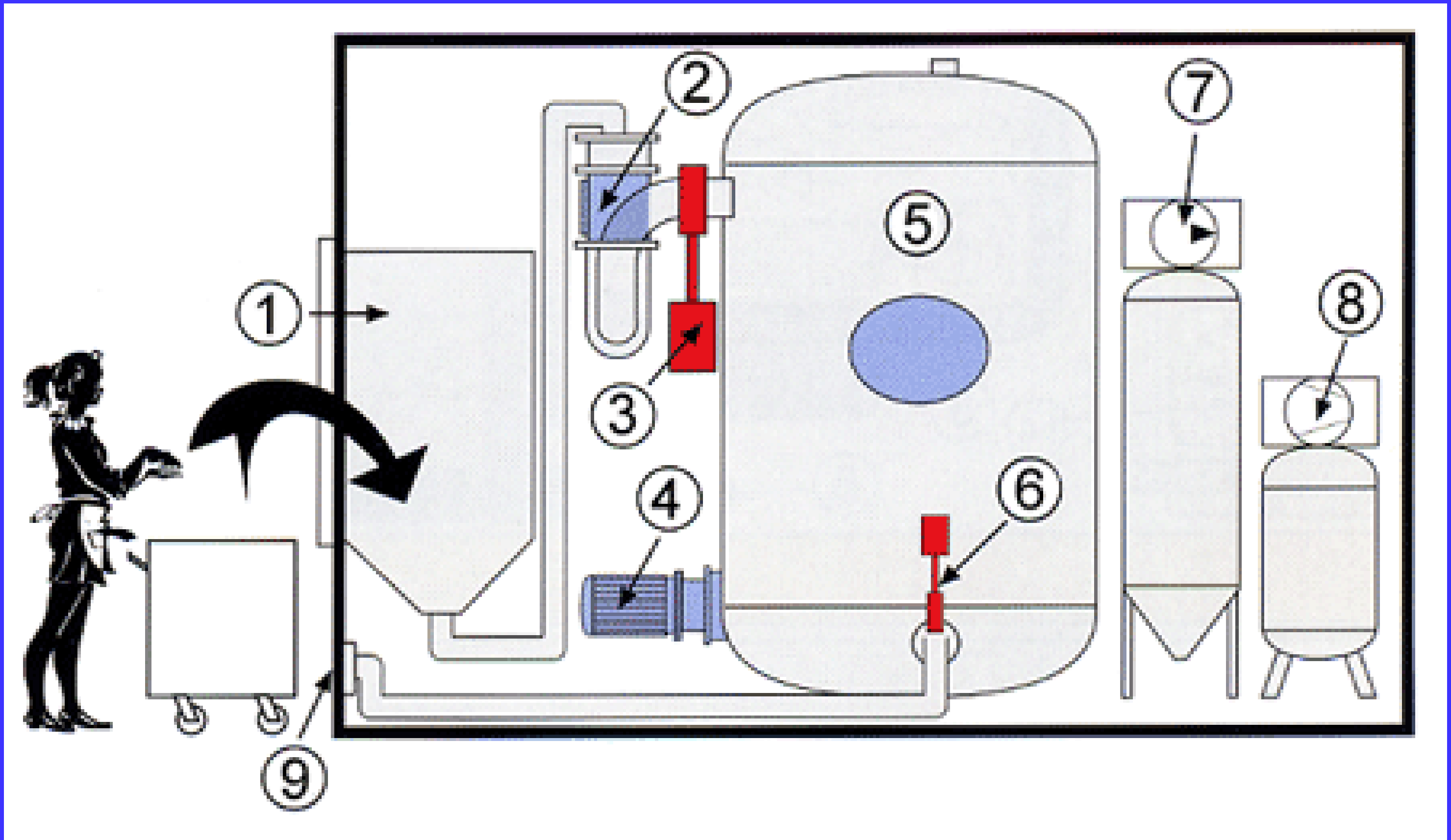
Food Waste Collection by Wet Waste Recovery System (WWRS)

- Manufactured in Germany by Rothenburg, GmbH
- Businesses in Germany, Denmark, Italy, Spain and Belgium use WWRS, also cruise ships, etc.
- Imported to United States by Ecology, LLC, Glendale, Wisconsin
- Demonstration installation at Pandl’s Restaurant in Bayside, WI (under DNR Solid Waste Reduction and Recycling Grant)
- Other food waste recovery systems available (e.g., InSinkErator)

WWRS Process

- WWRS converts food waste into a slurry
- Food waste slurry is stored in a holding tank
- The demonstration installation holding tank is emptied every two weeks via tanker truck
- The processed slurry is treated in anaerobic digesters
  - Methane would be created for renewable energy
  - Stabilized residual could be used as a soil amendment

Description of the WWRS



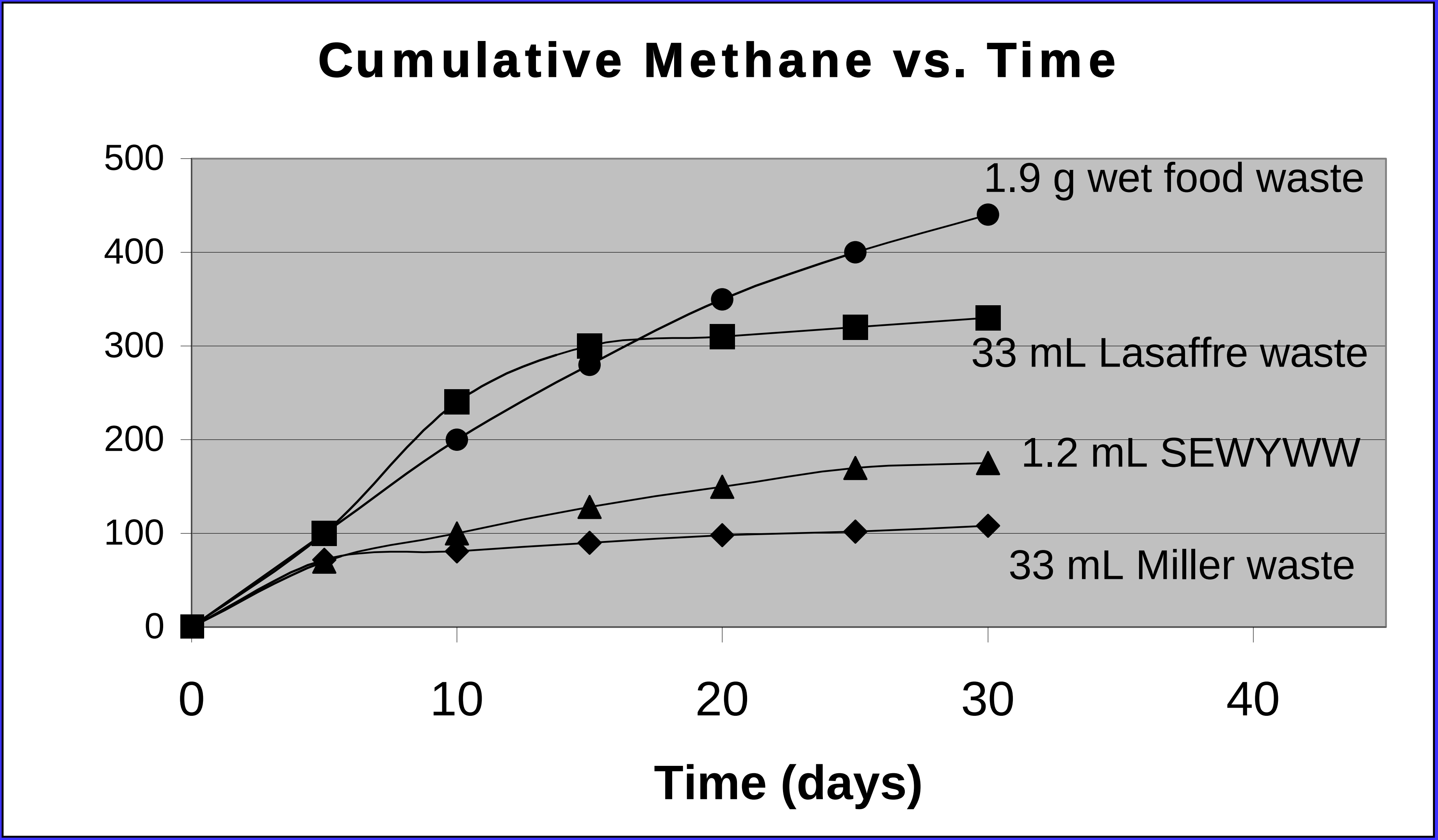
1. Input Station (Hopper)
2. Grinder
3. Input Knife Valve
4. Homogenizer
5. Holding Tank
6. Holding Tank Discharge Valve
7. Vacuum Pump
8. Compressor
9. Discharge Connector

Biochemical Methane Potential Procedure

160-mL serum bottles
50 mL of biomass (digester sludge from South Shore WWTP)
Various doses of high-strength wastes
Measure biogas production and methane content over time

Biogas Volume and Methane Content Analyses

Biochemical Methane Potential Results



Overall BMP Results

Characteristics	Miller Brewing	Lesaffre Yeast	SE WI Products	Food waste
BMP ($mlCH_4/gCOD$)	413±19	2274±338	943±454	488±262
Biogas % CH_4	58±6	60±3	69±1	68±2
Max. CH_4 Production rate (ml/day)	17	36	17	19
VS Biomass (g)	0.48	0.61	0.39	0.54
Max. Sp. CH_4 Production rate ($mlCH_4$/g VS-day)	35.4	59.0	43.60	35.2

Stoichiometry: 395 mL methane/g COD at 35°C

Full-Scale Testing at South Shore Wastewater Treatment Plant

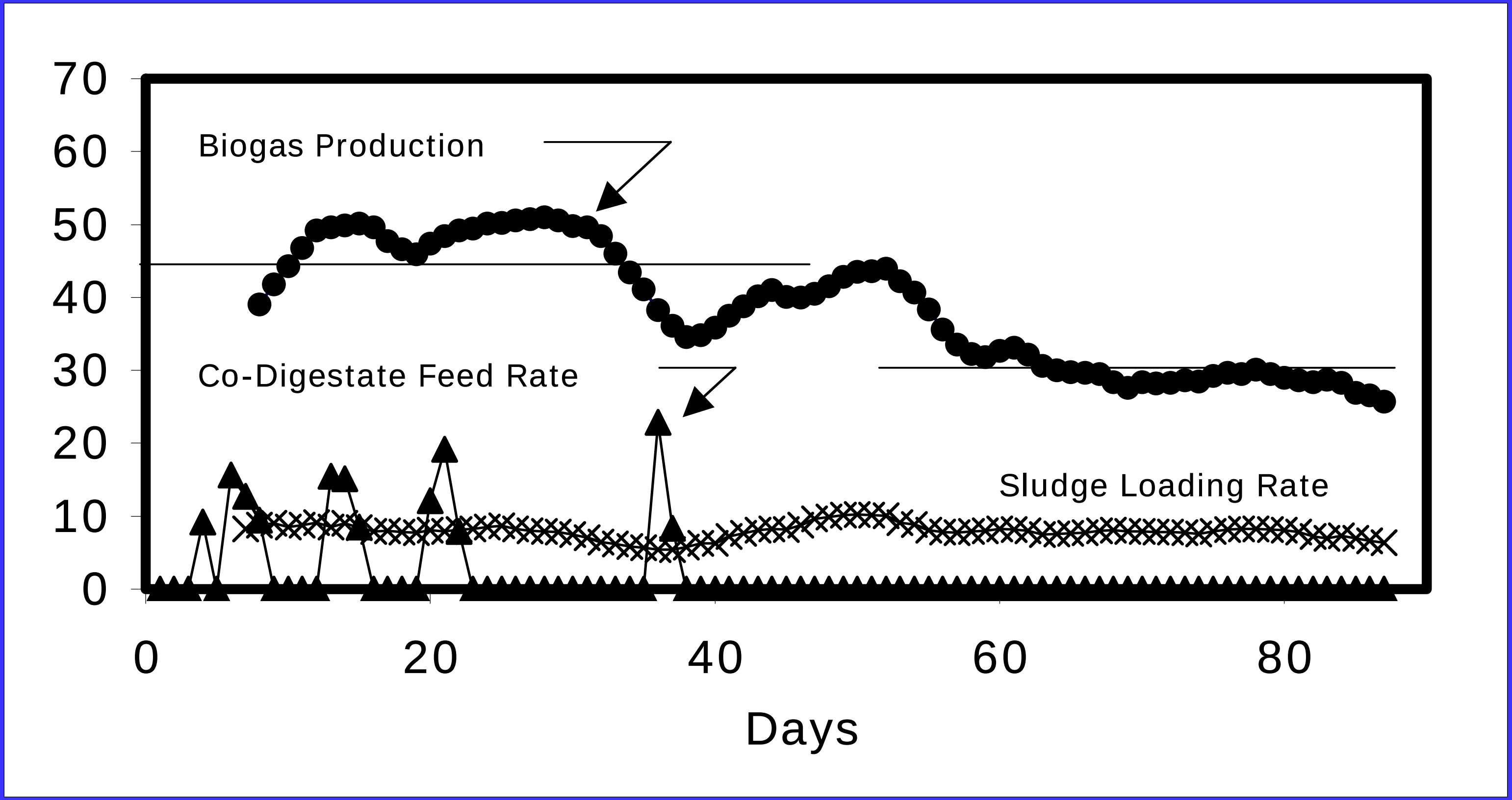
Biogas and Methane Production During and After SEWYWW Addition

Period*	No. of days	Biogas production (ft3CH4/tVS-d)	Biogas Production (ft3CH4/lb VS-d)	Methane Production (ft3CH4/tVS-d)	Methane Production (ft^3CH_4/lb VS-d)
1	32	26,300	13	15,800	7.9
2	45	17,900	8.9	10,500	5.2
3	31	17,200	8.6	10.300	5.2

* Period 1: 32 days during which SEWYWW was added to the digester (6/4/04 to 7/9/04).

Period 2: The 45 days after addition of SEWYWW (i.e., 3 SRTs) (7/9/4 to 8/19/04).

Period 3: The 31 days after Period 2 (8/19/04 to 9/20/04).



Full-Scale Co-Digestion of Yeast Waste

Biogas production (circles, 7-day running average, ML/day), co-digestate feed rate (triangles, lpm), and sludge loading (7-day running average, tonnes/day x 10^{-1}) during co-digestion of Food Flavorings Production Waste (Days 1 to 50) and control period (Days >50).

Average sludge loading rate = 80 tonnes/day.

Waste to Energy Values

Maximum Methane Production	ft^3/lb COD (SCF)	5.6	
CH_4 Heat Content	Btu/ft^3	950	
Biogas to Electricity Conversion	Btu/kWh (34% efficiency)	10,000	
Average Home Electricity Usage	kWh/day	25	
CO_2 Avoidance from Bituminous Coal	lb/kWh	2	
Average We Energies CO_2 Emissions	lb/kWh	1.8	

Methane/Energy from Co-Digestion

Waste	Waste Production Rate (ML/year)	Average COD (g/L)	Estimated CH_4 Production (ML/day)	Methane Energy (1000 MJ/day)	Average US Homes Provided Electricity	Estimated CO_2 Emissions Avoidance (Tonnes/yr)
Aircraft Deicing Fluid	1.26	260	0.32	11	41	350
Food Flavorings Production	2.08	85.6	0.17	6.0	22	190
Restaurant	0.05	438	0.014	0.50	1	16
Sum					64	556 ($2,224/yr @$4/ton)

Pandl’s Restaurant Co-Digestion Synopsis

- Restaurant produces 60 Kg of waste COD per day
- It is estimated that 40 Kg COD settle in the primary clarifier, pass the sludge screens and is conveyed to the anaerobic digester at SSWWTP
- The digested COD can produce 780 SCFD of methane
- The methane is equivalent to 780,000 BTU per day
- The methane can be used to generate 78 kw-hr/day (approximately 3 average households)

SEWYWW Co-Digestion Synopsis

- **SEWYWW can be added to the digesters at a rate of two 5000-gallon truckloads per week (1 gpm); trucking costs approximately $30,000/year**

- **According to BMP results: Biogas production would increase by 13,800 SCFD methane**
  - **This is equivalent to 13,800,000 BTU/day**
  - **This can be used to generate 1380 kw-hr/day of electricity**
  - **This can power 55 average households**
  - **This is worth $30,000 per year at $0.06/kw-hr**

- **According to full-scale results: biogas production increased by163,000 SCFD methane**
  - **This is equivalent to 163,000,000 BTU/day**
  - **This can be used to generate 16,300 kw-hr/day of electricity**
  - **This can power 650 average households**
  - **This is worth $357,000 per year at $0.06/kw-hr**

Conclusions

- Results of BMP and bench-scale testing demonstrate that all 4 high-strength wastes are amenable to co-digestion.

- It was advisable to add food waste from Pandl's Restaurant to the primary clarifiers and then pass through existing screens to remove large particles before digestion.

Conclusions

- Based upon bench- and full-scale testing, Pandl's Restaurant and SEWYWW can be co-digested with no adverse impacts on operation of digesters, pumps, heat exchangers, and appurtenances.

- The extremely large increase in biogas production during SEWYWW co-digestion is possibly from methanogen stimulation from trace nutrients. It is possible that this waste could be used as a trace nutrient source.

Conclusions

- It is recommended that treatment plant personnel consider repeating the full-scale co-digestion of SEWYWW. Continuous co-digestion may lead to sustained increase in biogas production.

- Full-scale investigations regarding the use of yeast production wastes as nutrient supplements to increase biogas production is recommended.