Effects of Climate Region, Reaction Temperature and Feed Composition on Microbial Community and Anaerobic Digestion Performance

Rui Chena, Mariana Murillob, Yuan Zhonga, Terry Marsha, Lorena Uribe Loriob, Lidieth Uribe Loriob, Dana Kirka, Wei Liaoa*

a. Anaerobic Digestion Research and Education Center (ADREC), Michigan State University
b. Center of Microbiology, University of Costa Rica
*: Corresponding author

July 15, 2014
2014 ASABE conference

MICHIGAN STATE UNIVERSITY

Outline

UNIVERSIDAD DE COSTA RICA

- Objective
- Investigation of effects of climate and culture conditions on anaerobic microbial communities
- Pilot-scale digestion in Central America
- Conclusions

MICHIGAN STATE UNIVERSITY

Objective

UNIVERSIDAD DE COSTA RICA

Investigate the effects of climate region and culture conditions on anaerobic microbial community to conclude the key factors that influence the digestion performance

1 L lab-scale anaerobic digesters

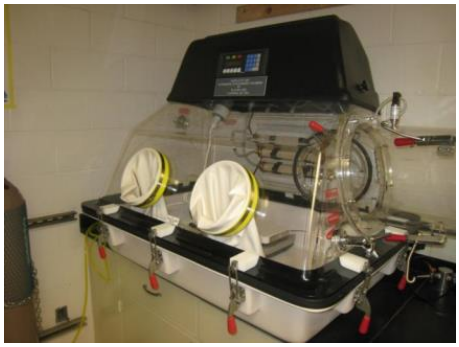
20 m3 pilot thermophilic digester at Costa Rica

Lab experiment set-up

- Experiment
  - HRT: 20 days
  - Temp.: 35 and 50°C
  - Total solids: 5%
  - pH: 7
  - Feedstock: chicken litter, dairy manure, and food waste
  - Location: Michigan and Costa Rica
  - Experiment duration: 90 days

1 L anaerobic bioreactors

- Parameters
  - Biogas production
  - TS reduction
  - Carbohydrate reduction
  - Microbial communities



Anaerobic chamber for feeding and sampling

1. Effects of climate and culture conditions

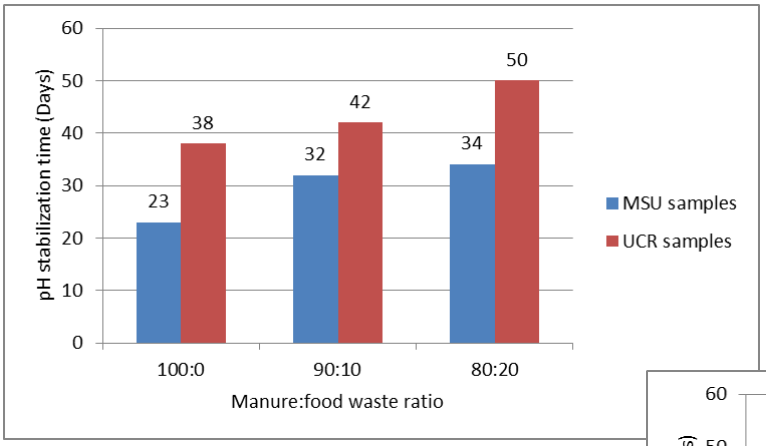
Feedstock characteristics*

		C(wt%)	N (wt%)	C/N	Glucan (wt%)	Xylan (wt%)	Lignin (wt%)
UCR	Dairy manure	40.6 ± 1.0	2.4 ± 0.1	16.7	14.7 ± 0.8	12.6 ± 1.3	27.3 ± 1.5
	Chicken litter	36.8 ± 0.9	3.3 ± 0.2	11.1	25.3 ± 1.0	9.3 ± 0.3	6.8 ± 0.3
	Food waste	**44.5 ± 1.1**	**2.6 ± 0.1**	**17.1**	**37.3 ± 0.3**	**5.2 ± 0.3**	**16.6 ± 0.7**
MSU	Dairy manure	43.7 ± 0.6	2.1 ± 0.2	20.6	22.7 ± 0.7	13.9 ± 0.5	28.4 ± 1.0
	Food waste	**47.8 ± 0.1**	**5.3 ± 0.1**	**9.0**	**20.5 ± 2.3**	**4.7 ± 0.6**	**11.3 ± 1.1**

*: Data are average of three replicates with standard deviation

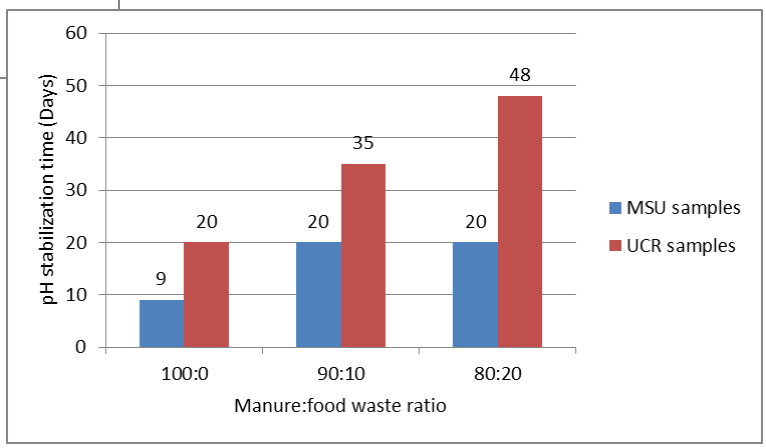
2. Pilot-scale Digestion in Central America

Effects of location, feedstock composition and temperature on digestion stabilization *



Culture temp.: 35°C

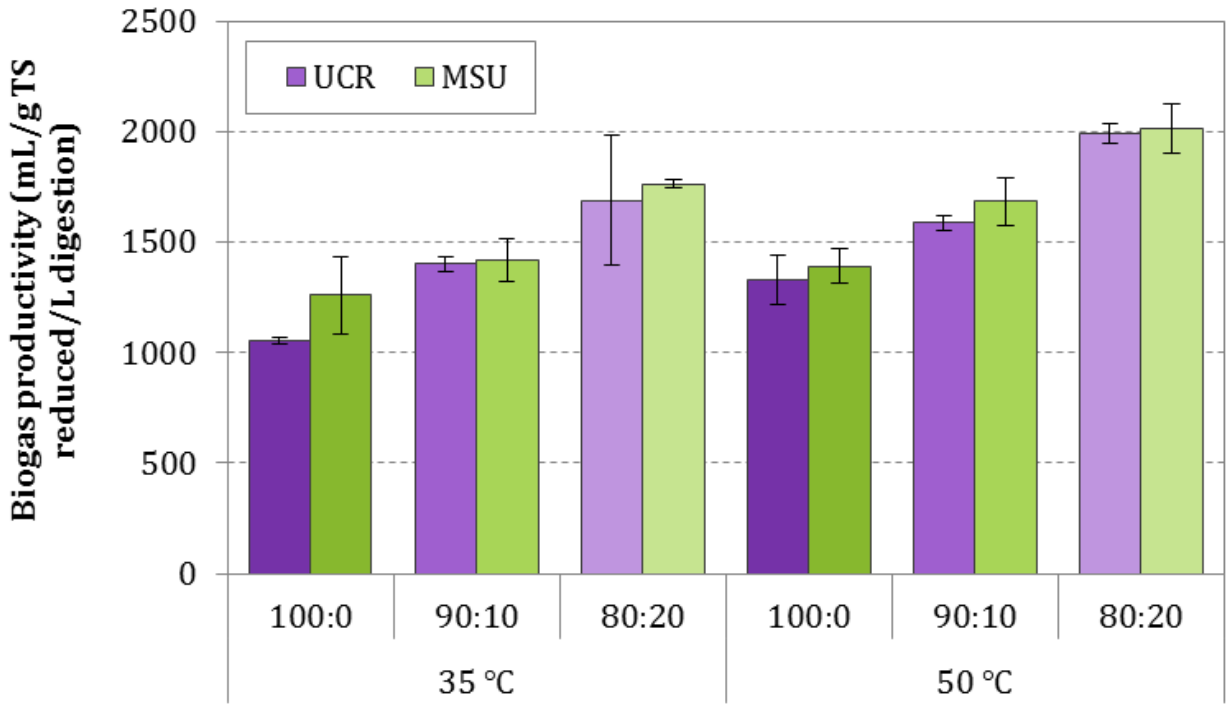
Culture temp.: 50°C



*: Digestion stability is based on pH

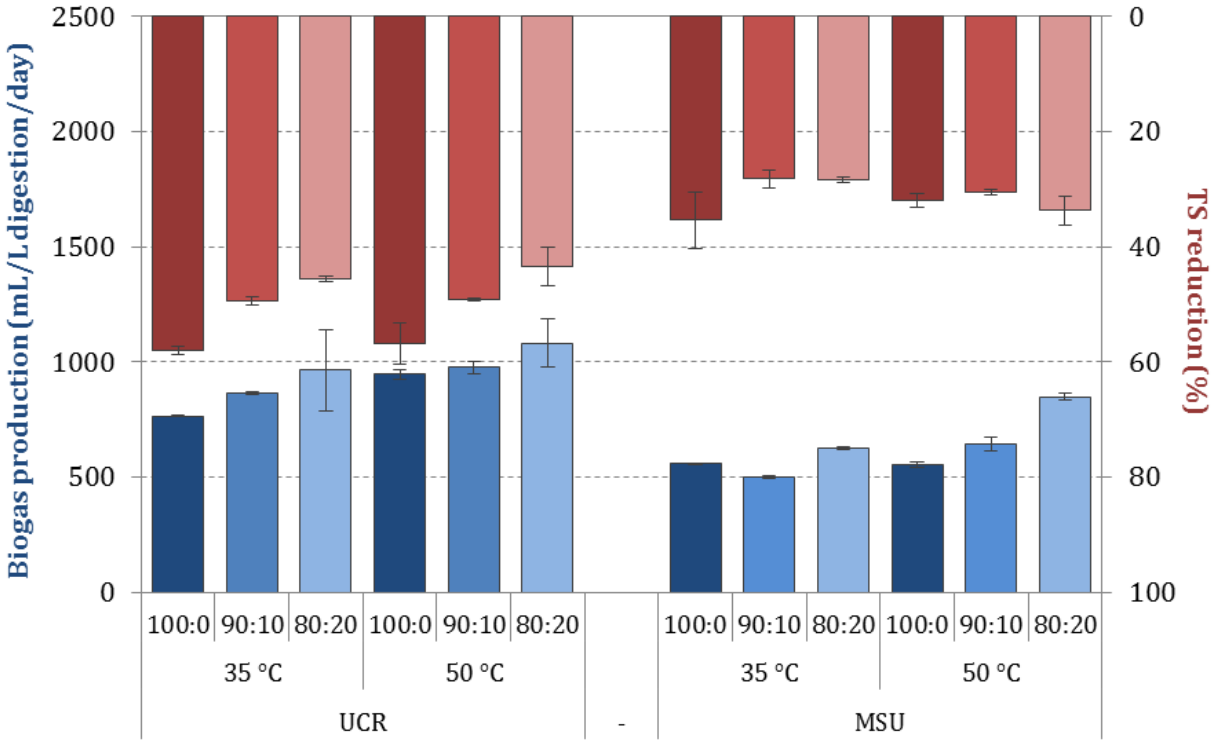
2. Pilot-scale Digestion in Central America

Effects of location, feedstock composition and temperature on digestion performance



2. Pilot-scale Digestion in Central America

Effects of location, feedstock composition and temperature on digestion performance



Digestion performance of gas production and fiber reduction*

			Daily biogas production (mL/L digestion/day)	CH4 content (%)	TS reduction (%)	Glucan reduction (%)	Xylan reduction (%)
UCR	35 °C	100/0	764.8 ± 1.5	62.0 ± 0.1	58.0 ± 0.8	77.5 ± 1.7	64.7 ± 0.6
		90/10	865.3 ± 5.4	59.4 ± 2.0	49.4 ± 0.8	74.9 ± 1.4	56.0 ± 0.7
		80/20	963.3 ± 177.8	59.1 ± 0.3	45.6 ± 0.5	74.7 ± 2.5	51.9 ± 1.6
	50 °C	100/0	946.1 ± 20.6	59.7 ± 1.2	56.9 ± 3.6	70.0 ± 1.6	59.5 ± 2.4
		90/10	976.3 ± 25.1	67.0 ± 0.4	49.2 ± 0.2	67.4 ± 0.7	51.5 ± 0.5
		80/20	1082.7 ± 107.0	68.2 ± 0.2	43.5 ± 3.3	65.5 ± 0.8	41.1 ± 0.6
MSU	35 °C	100/0	558.9 ± 2.8	58.3 ± 1.0	35.4 ± 5.0	35.6 ± 4.1	33.9 ± 4.8
		90/10	499.1 ± 8.3	65.2 ± 0.5	28.2 ± 1.5	36.8 ± 0.7	25.1 ± 0.5
		80/20	626.5 ± 5.7	60.1 ± 0.3	28.4 ± 0.5	34.3 ± 4.0	17.9 ± 0.3
	50 °C	100/0	554.4 ± 12.4	59.0 ± 1.7	31.9 ± 1.1	44.2 ± 1.1	27.7 ± 0.5
		90/10	642.1 ± 28.7	58.6 ± 1.7	30.5 ± 0.6	44.1 ± 6.0	29.1 ± 6.6
		80/20	848.8 ± 16.2	67.6 ± 0.1	33.7 ± 2.5	40.3 ± 4.9	23.4 ± 3.9

*: Data are average of three replicates with standard deviation

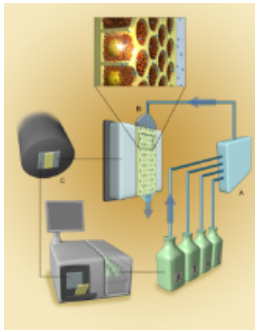
MICHIGAN STATE UNIVERSITY

1. Effects of climate and culture conditions

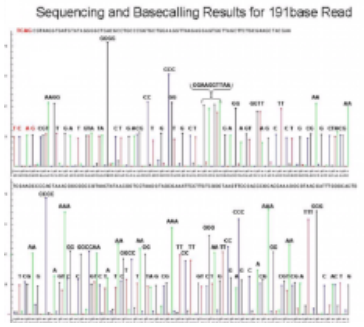
UNIVERSIDAD DE COSTA RICA

Microbial community in anaerobic digestion

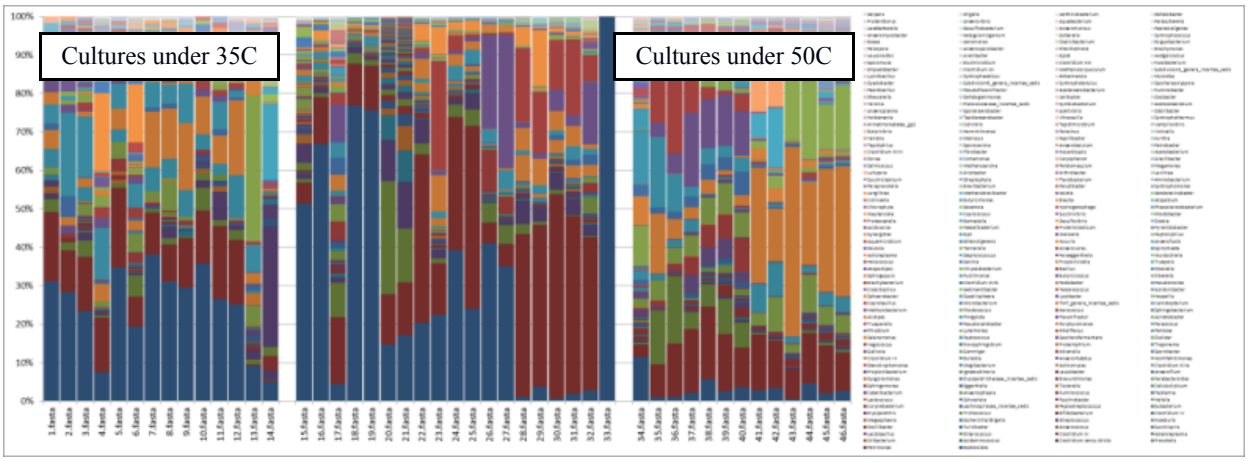
- **Primers for PCR amplification 16S rRNA gene:**
  Universal bacterial primers 357f (5'-CCTACGGGAGGCAGCAG-3') and 926r (5'-CCGTCAATTCMTTTRAGT-3')
- **Primers for 454 sequencing:**
  Human Microbiome Project (HMP) primers targeting the V3-V5 region of 16S rRNA gene



GT 454 FLX sequencer



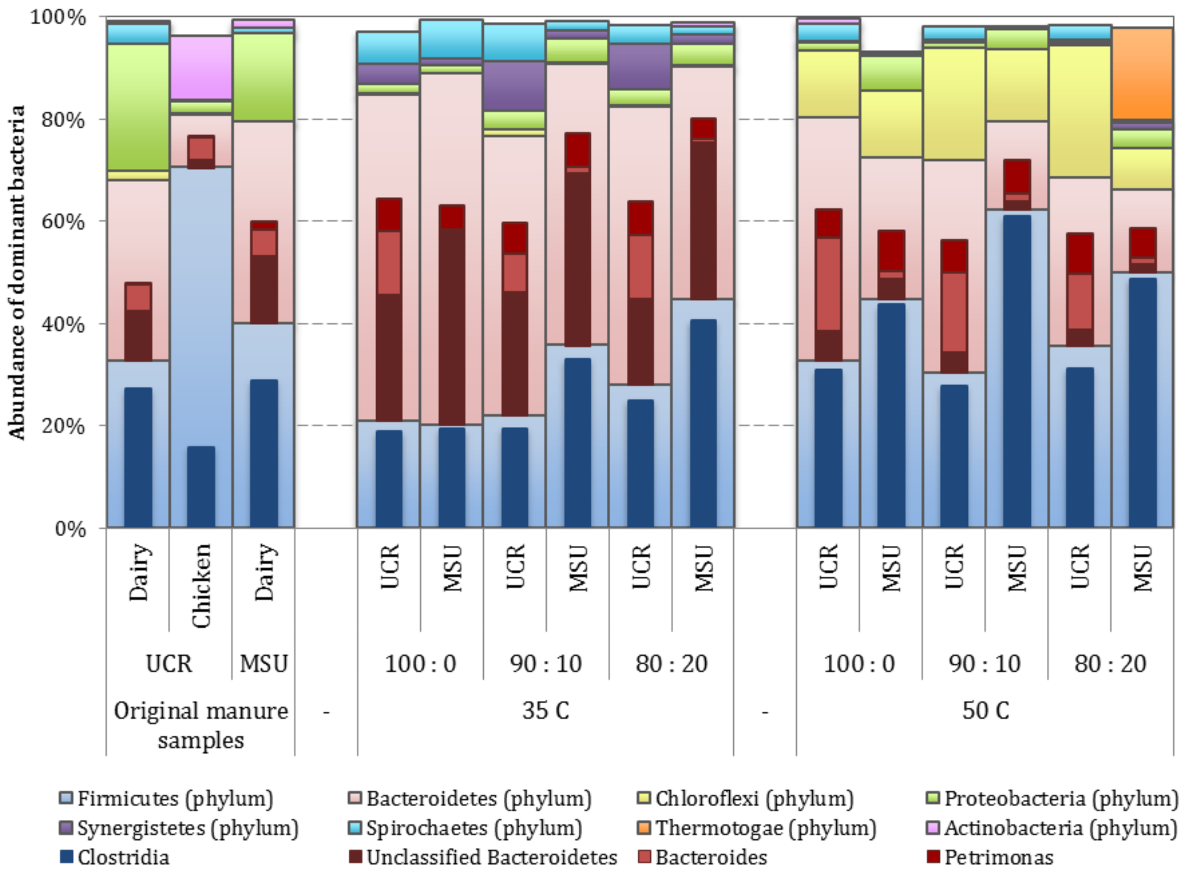
Readings from the sequencer



Abundances of bacterial community

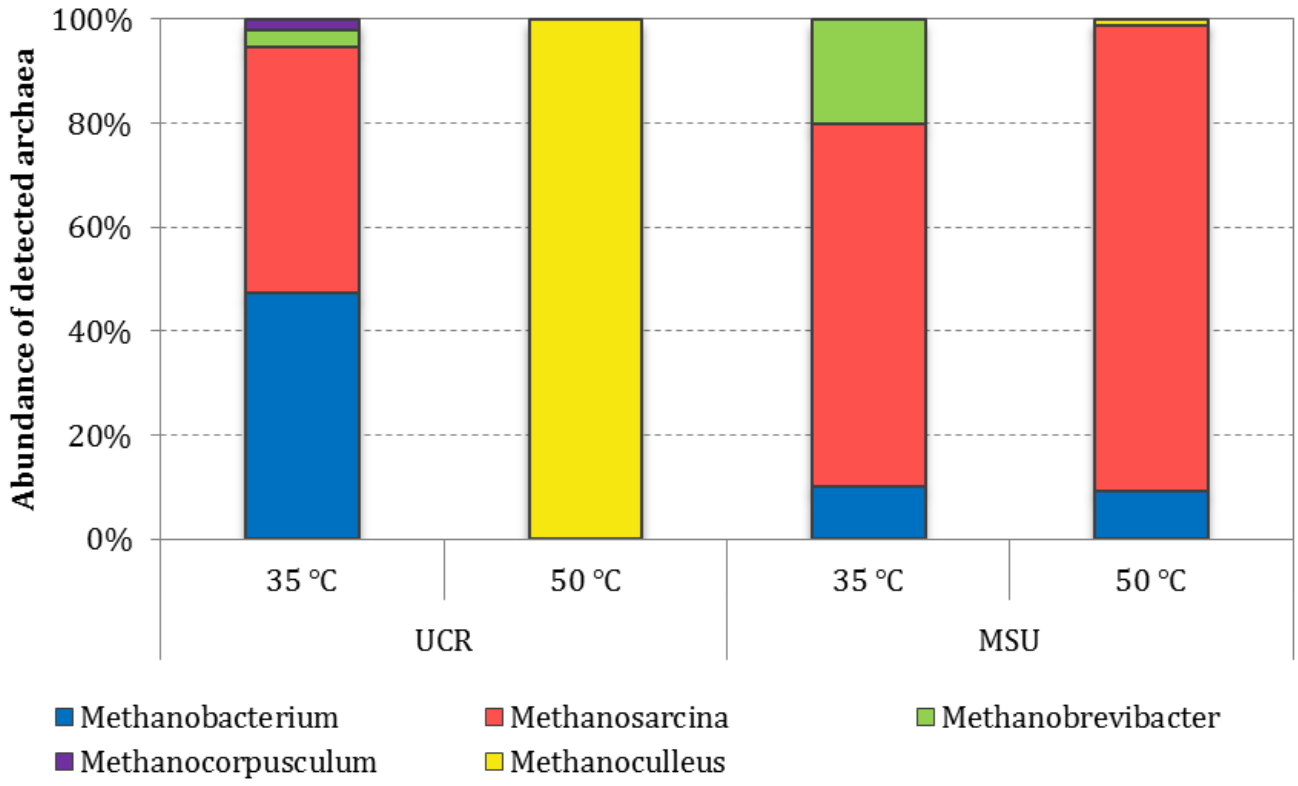
2. Pilot-scale Digestion in Central America

Abundance of dominant bacteria



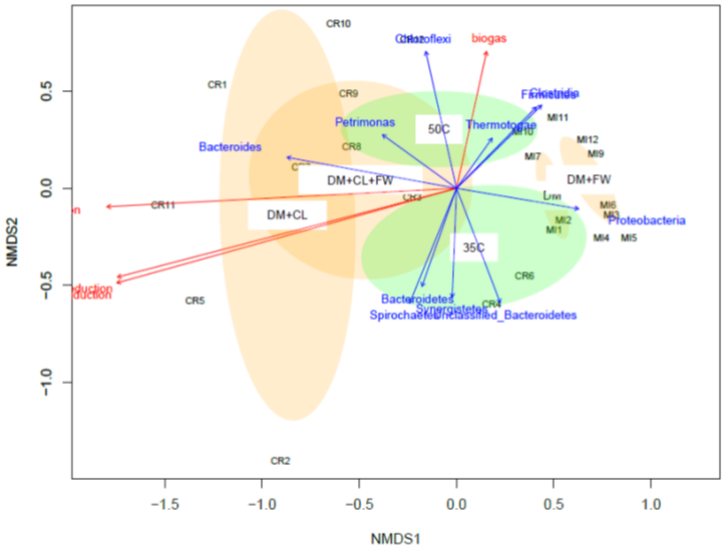
2. Pilot-scale Digestion in Central America

Abundance of dominant archaea



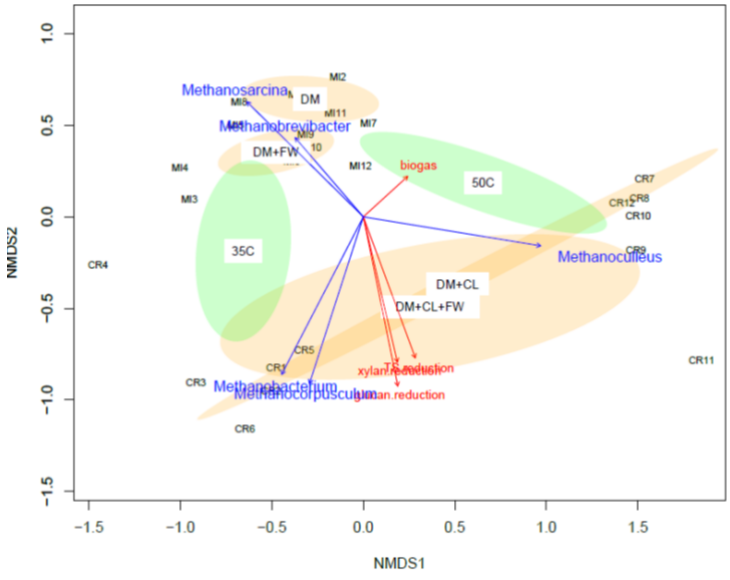
2. Pilot-scale Digestion in Central America

Non-metric Multi-dimensional Scaling (NMDS) analysis of microbial community



Interaction between **Bacteria** and digestion performance

Interaction between **Archaea** and digestion performance

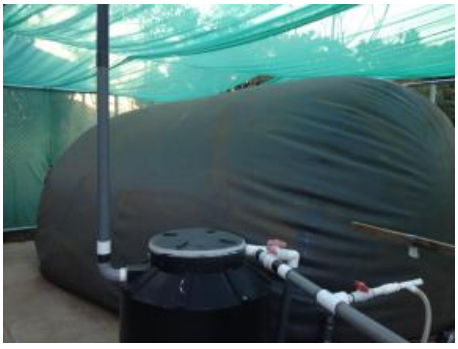


Pilot bioreactor system at the UCR Fabio Agricultural Experiment Station

Feeding unit

Bioreactor (20 m3)

Engines (16 kw x 2)

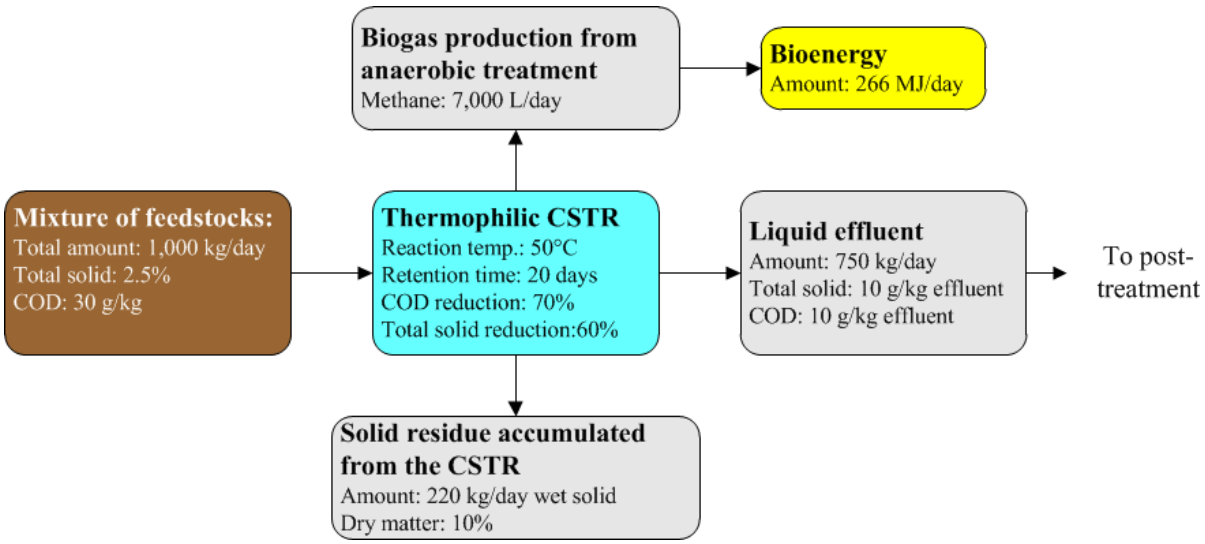


Biogas storage (60 m3)

Flare

Mass balance for the pilot scale digester

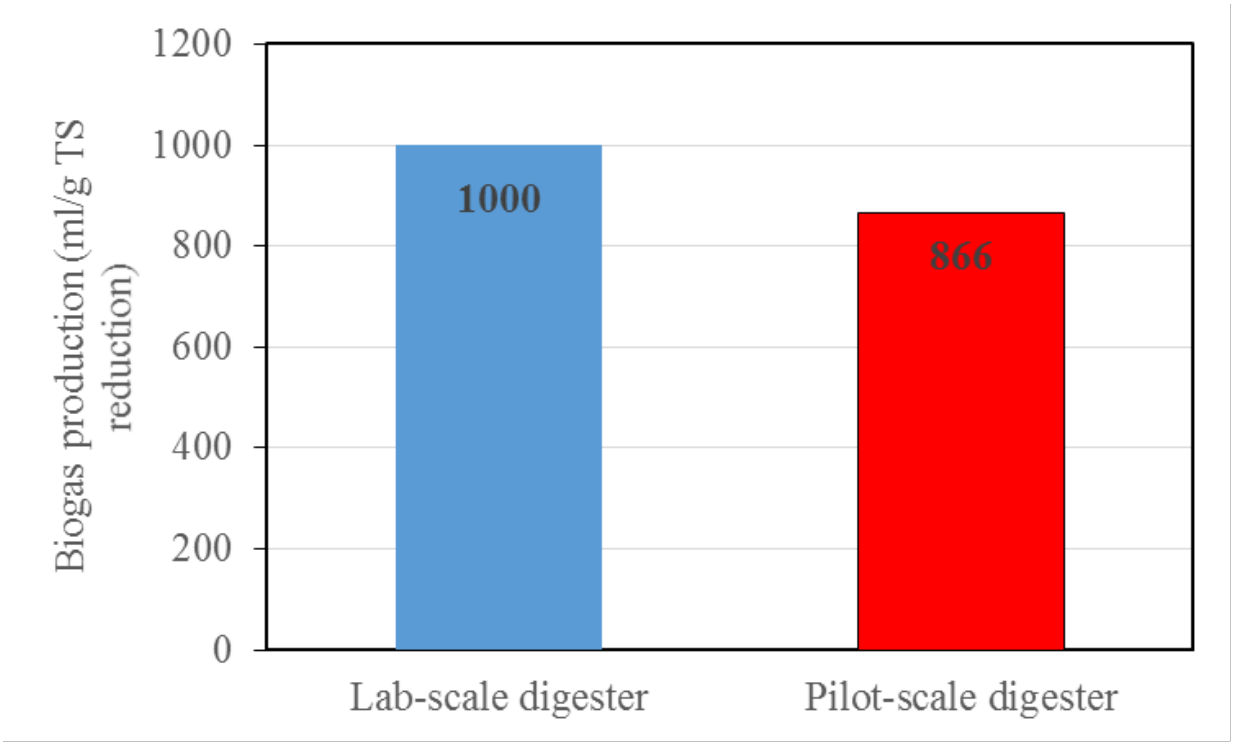
Mass balance for the solar-bio system on 1,000 kg of mixed chickendairy manure and food wastes



- **Generating 25 kWh electricity per day**
- **Producing 2 gasoline gallon equivalent (GGE) renewable fuel per day**

2. Pilot-scale Digestion in Central America

Performance comparison between lab- and pilot-scale *



*: Under the same operational conditions

MICHIGAN STATE UNIVERSITY

Conclusions

UNIVERSIDAD DE COSTA RICA

1. **Biogas productivity was more dependent on the reaction temperature than climate region.**
2. **The manure-to-food waste ratio in feedstock from the same climate region did not have any significant impact on microbial structure.**
3. Both bacterial and archaeal communities were distinctly different between locations and temperature settings, and they are significantly correlated with biomass reduction rate.
4. The assembly of dominant bacteria (*Bacteroidetes*, *Clostridia*, *Bifidobacterium*) and methanogenic archaea (*Methanobacterium* and *Methanosarcina*) proved that microbial structure shifted corresponding to the change in temperature and climate region.
5. Applying the optimal conditions concluded from the lab study to the pilot-scale digester demonstrated a consistent performance in the tropic region.

Acknowledgement

Technical Supports

MSU Research Technology Support Facility (MSU RTSF)
UCR Fabio Baudrit Agricultural Experiment Station

Financial Supports

The U.S. Department of State

MICHIGAN STATE UNIVERSITY

Thank You!

UNIVERSIDAD DE COSTA RICA

The MSU Anaerobic Digestion Research and Education Center

Main building

High-bay area

Wet labs

Hot room

CSTR system
(2000 m3, 0.5 MW)

Plug flow system
(1000 m3)

Algal race-way system
(1,600 m2 pond)

Solar panels

Homepage: http://www.egr.msu.edu/bae/adrec/