Diverting Food Waste for Local Bioenergy Production through Anaerobic Digestion

Ryan E. Graunke[1] and Ann C. Wilkie[2]

[1]School of Natural Resources and Environment

[2]Advisor, Soil and Water Science Department

Abstract

Humans are currently facing many global challenges in achieving sustainability. Among these challenges are unsustainable waste production and fossil fuel consumption. Society produces a myriad of different wastes, many of which have potential to be recovered or recycled as energy or material resources. While a variety of different technologies exist to recover energy from some of these wastes, anaerobic digestion offers the opportunity to recover energy from a largely untapped resource: food waste. Food waste is a major problem for Florida, with 1.7 million tons generated annually in the state which is currently buried in landfills. Anaerobic digestion can not only divert this waste from landfills, but can recover usable bioenergy as well. Anaerobic digestion is a microbial process by which organic matter is degraded under anaerobic conditions. The resulting methane-rich (60-80%) biogas can be utilized as a bioenergy replacement for natural gas. These uses include electricity generation, water and space heating, cooking, or as a vehicle fuel in compressed natural gas vehicles. In addition, the effluent from anaerobic digesters can be utilized as an organic fertilizer because the nutrients within the feedstock are conserved and solubilized into plant-available forms (i.e. ammonium). Food waste makes an ideal feedstock for anaerobic digestion due to its rapid degradability and high organic matter content, which corresponds to a high methane production potential. Because anaerobic digestion is a scalable technology, food waste digestion allows for distributed energy generation throughout the community. Food waste is currently produced from many locations including food processors, grocery stores, restaurants, schools, prisons, and households. While a centralized food waste digestion system could handle the food waste from an entire municipality, there are many obstacles to overcome for a large-scale digester. These obstacles include logistics, transportation, and high capital costs. Small-scale food waste digestion may be a more feasible option than large-scale digestion for initial adoption of the technology. This study assessed the potential for small-scale food waste digestion at local food waste generators. Food waste audits were conducted at schools and restaurants to determine the quantity of food waste generated. Food waste samples were analyzed for moisture/organic content, pH, and chemical oxygen demand. Based on this analysis, annual methane production potentials were estimated for each location. These estimates were extrapolated to determine the statewide methane production potential of Florida's food waste.

Introduction

- Food waste is a major problem in Florida; 1.7 million tons are landfilled annually (FDEP 2009).
- Food waste generates methane in landfills, which contributes to global methane emissions and climate change.
- Anaerobic digestion of food waste diverts the material from landfills and produces a renewable bioenergy (Graunke and Wilkie 2008).
- Anaerobic digestion is a natural, microbial process that converts organic material into methane-rich biogas (Wilkie 2008).
- Biogas can be utilized similarly to natural gas for cooking, heating electricity, vehicle fuel, etc. (Wilkie 2007).
- Remaining material after digestion is a nutrient-rich biofertilizer (Wilkie 2006).
- Small-scale anaerobic digestion of food waste can develop the food waste digestion infrastructure in the US and Florida.
- With on-site digestion, biogas can be utilized directly by the food waste generator (e.g. used for cooking in the kitchen).
- Local schools and restaurants were selected for this project as potential small-scale food waste digestion pilot locations.
- Waste audits were performed to determine the biogas potential of food waste generated at these locations.

Materials and Methods

Waste Audits

- Waste audits were conducted for two weeks at three local schools and three local restaurants (Table 1).
- All food waste was collected from both the kitchen (pre-consumer) and dining areas (post-consumer), where applicable (Table 2).
- Student and customer counts were collected for data normalization.
- Data was extrapolated to estimate Florida's food waste generation from schools and restaurants using state student enrollment (FDOE 2010) and restaurant employees (FDBPR 2010).

Waste Characterization

- Each day, food waste was weighed and ground through an in-sink food disposal or manual meat grinder.
- A 2 kg representative sample was obtained for laboratory analysis.
- Total solids (TS) and volatile solids (VS) were measured on all samples using standard methods (APHA 2005).
- Chemical oxygen demand (COD) was measured on a wet weight (ww) basis for all samples. The COD represents the total COD of the ground food waste.
- Methane potential was based on the stoichiometric COD to methane ratio (0.35 L CH_4/g COD @ STP) (Speece 2008) assuming 90% COD conversion.

Table 1: Waste Audit Locations

Name	Description	Students/ customers (employees)
Oak Hall	Private K-12 school (no cafeteria)	333±3
JJ Finley	Public elementary school	407±4
Lofton	Public high school	219±10
Rolls 'n Bowls	Quick-service Asian restaurant	273±44 (30)
Satchel's	Gourmet pizza restaurant	442±96 (45)
The Top	Full-service restaurant	303±59 (45)

Table 2: Description of food waste generated at each location

Location – Type	Food Waste Description
Oak Hall	Boxed lunches leftovers, mostly processed foods
JJ Finley	Plate scraps, high quantity of milk
Lofton – Dining	Plate scraps
Lofton – Kitchen	Kitchen scraps (rice, vegetables)
Rolls 'n Bowls	Kitchen scraps (rice, vegetable and meat trimmings)
Satchel's – Dining	Plate scraps, high quantity of pizza crust
Satchel's – Kitchen	Kitchen scraps (vegetable trimmings)
The Top – Dining	Plate scraps, high quantity of liquids
The Top - Kitchen	Kitchen scraps (vegetable and meat trimmings)

Figure 1: Food waste from schools and restaurants

Figure 2: Portable food waste digester for demonstration at schools and restaurants

Results

- The characteristics of food waste (TS,VS, and COD) varied depending on the type of food waste (Table 3).
- Restaurants had greater variation than schools in daily food waste generation on a COD basis (Figures 3 and 4).
- The Top had the greatest daily food waste generation on a wet weight, TS, and COD basis. Oak Hall had the lowest generation (Tables 4).
- Average daily and annual methane potential for each location ranged from an estimated 1.4-5.9 m^3/day and 243-1,526 m^3/year, respectively (Table 4 and Figure 5).

Table 3: Physiochemical characteristics of food waste collected during food waste audits

Location – Type	TS (%)	VS (%TS)	COD (g/kg ww)
Oak Hall	44.6 ± 3.7	83.7 ± 2.6	522.2 ± 57.0
JJ Finley	28.4 ± 3.0	91.6 ± 4.7	375.6 ± 38.8
Lofton – Dining	33.6 ± 3.1	90.5 ± 4.3	436.4 ± 44.8
Lofton – Kitchen	32.1 ± 9.6	91.0 ± 5.7	420.5 ± 117.4
Rolls 'n Bowls	22.3 ± 5.7	95.4 ± 1.4	271.7 ± 76.9
Satchel's – Dining	53.4 ± 2.8	92.1 ± 6.0	715.7 ± 53.9
Satchel's – Kitchen	9.1 ± 1.2	90.7 ± 1.8	100.1 ± 12.7
The Top – Dining	27.1 ± 3.8	93.0 ± 3.2	423.9 ± 52.3
The Top – Kitchen	18.7 ± 3.9	84.5 ± 10.0	248.3 ± 89.1

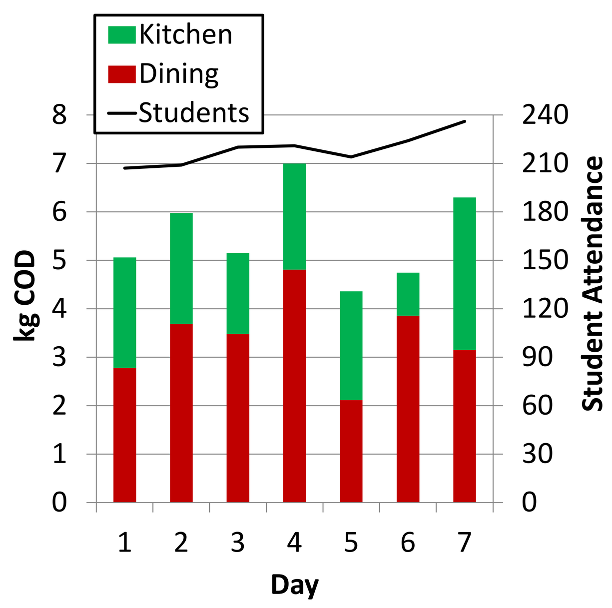

Figure 3: Daily generation at Lofton

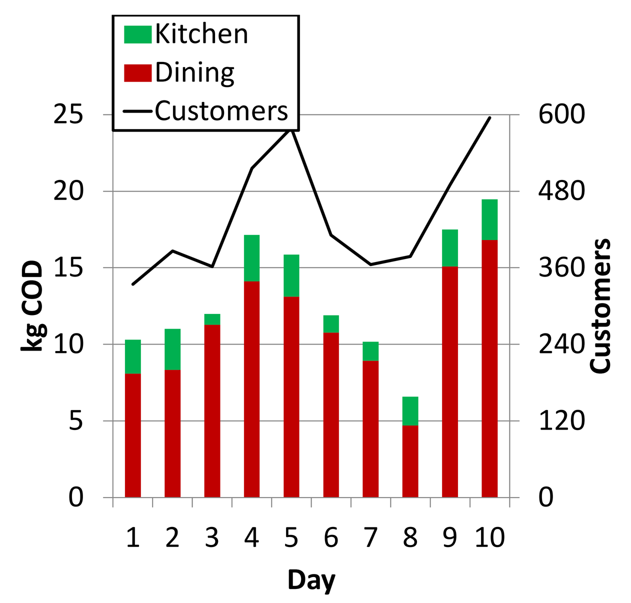

Figure 4: Daily generation at Satchel's

Table 4: Average daily food waste generation (ww, VS and COD basis) and estimated daily methane potential

Location	Wet Weight (kg)	VS (kg)	COD (kg)	Methane (m^3)
Oak Hall	8.2 ± 0.8	3.1 ± 0.5	4.3 ± 0.6	1.4 ± 0.2
JJ Finley	36.8 ± 5.7	9.5 ± 0.9	13.7 ± 1.3	4.3 ± 0.4
Lofton	13.2 ± 2.3	3.8 ± 0.8	5.5 ± 0.9	1.7 ± 0.3
Rolls 'n Bowls	20.3 ± 5.9	4.5 ± 2.2	5.7 ± 2.8	1.8 ± 0.9
Satchel's	36.4 ± 11.4	9.3 ± 2.8	13.2 ± 4.1	4.2 ± 1.3
The Top	56.0 ± 15.2	11.2 ± 3.8	18.6 ± 7.1	5.9 ± 2.2

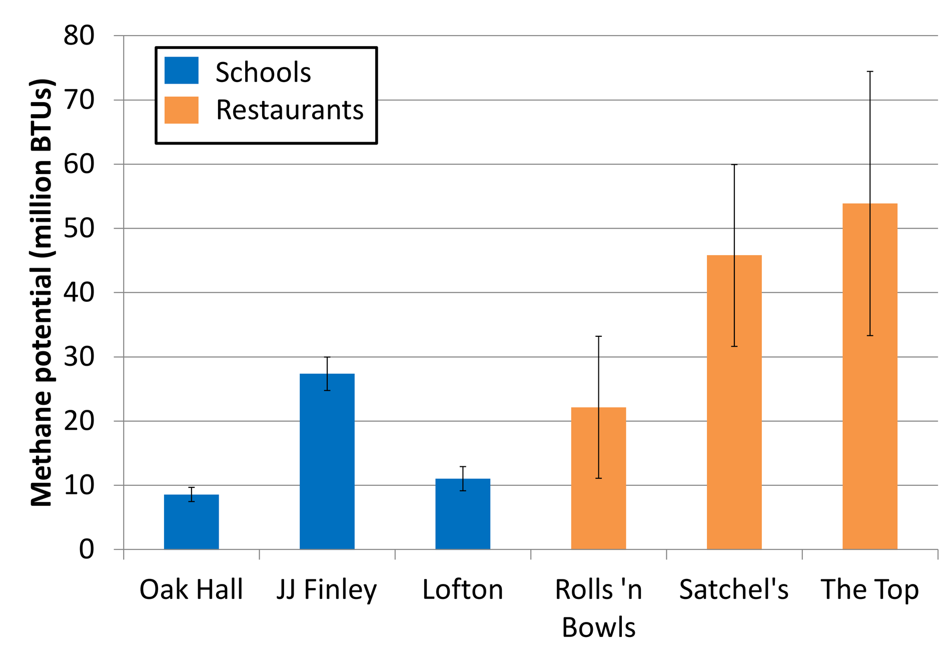

Figure 5: Annual methane potential through food waste digestion at local schools and restaurants

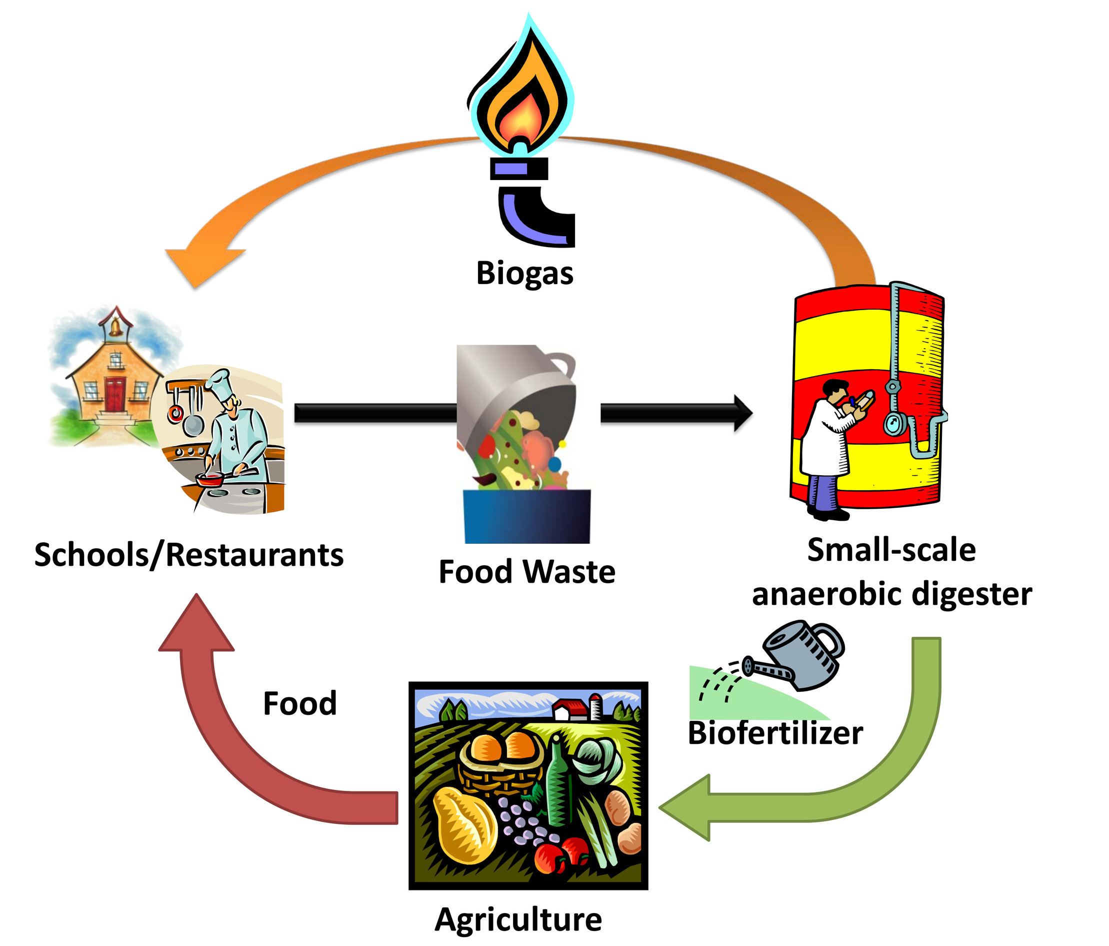

Figure 6: Closed-loop cycle of small-scale food waste digestion

Discussion

- Schools and restaurants generate a large, but variable, quantity of food waste.
- Food waste is an ideal feedstock due to a high COD content and high biodegradability.
- The scalability of anaerobic digestion can accommodate schools and restaurants of all sizes.
- The schools and restaurants directly benefit through reduced waste disposal costs and renewable energy from biogas, which creates a closed-loop sustainable cycle. (Figure 6).
- Based on these audits:
  - Florida's K-12 schools generate an estimated 30,100 tonnes (ww) of food waste annually
  - Florida's restaurants generate an estimated 152,000 tonnes (ww) annually.
- Estimated annual methane production from these sectors in Florida and Florida's 1.7 million annual tons of food waste:
  - ***Schools: 114 – 171 billion BTUs***
  - ***Restaurants: 216 – 957 billion BTUs***
  - ***Florida: 3.3 – 9.6 trillion BTUs***

Acknowledgements

This work is funded by a grant from the Hinkley Center for Solid and Hazardous Waste Management

References

APHA (2005). Standard Methods for the Examination of Water and Wastewater, 21th ed. American Public Health Association, Washington, DC.

FDBPR (2010) *Division of hotels and restaurants annual report: FY 2009-2010*; Florida Department of Business and Professional Regulation, Tallahassee, FL http://www.myfloridalicense.com/dbpr/hr/reports/annualreports/documents/ar2009_10.pdf.

FDEP (2009) *Solid Waste Management in Florida 2009 Annual Report*; Florida Department of Environmental Protection Office of Solid and Hazardous Waste, Tallahassee, FL http://www.dep.state.fl.us/waste/categories/recycling/SWreportdata /09_data.htm.

FDOE (2010)*Membership in Florida's Public Schools, Fall 2010*; Florida Department of Education, Tallahassee, FL: http://www.fldoe.org/eias/eiaspubs/default.asp.

Graunke, R.E. and Wilkie, A.C. (2008). Converting Food Waste to Biogas: Sustainable Gator Dining. *Sustainability – The Journal of Record*, 1 (6), 391-394.

Speece, R.E. 2008. *Anaerobic Biotechnology and Odor/Corrosion Control for Municipalities and Industries*. Archae Press, Nashville, TN.

Wilkie, A.C. (2006). The other bioenergy solution: The case for converting organics to biogas. *Resource: Engineering & Technology for a Sustainable World* 13 (8):11-12. October 2006. American Society of Agricultural and Biological Engineers (ASABE), St. Joseph, Michigan.

Wilkie, A.C. (2007). Eco-Engineering a Sustainable Society. R*esource: Engineering & Technology for a Sustainable World* 14(6):19-20. August 2007. American Society of Agricultural and Biological Engineers (ASABE), St. Joseph, Michigan.

Wilkie, A.C. (2008). Biomethane from biomass, biowaste and biofuels. In: *Bioenergy.* p.195-205. J.D. Wall, C.S. Harwood and A. Demain (eds,). American Society for Microbiology Press, Washington, DC.