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Chemical composition and methane potential of commercial food wastes

Victoria M. Lopez, Florentino B. De la Cruz, Morton A. Barlaz *

Department of Civil, Construction, and Environmental Engineering, NC State University, 2501 Stinson Drive, Raleigh, NC 27695, USA

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ABSTRACT

There is increasing interest in anaerobic digestion in the U.S. However, there is little information on the characterization of commercial food waste sources as well as the effect of waste particle size on methane yield. The objective of this research was to characterize four commercial food waste sources: (1) university dining hall waste, (2) waste resulting from prepared foods and leftover produce at a grocery store, (3) food waste from a hotel and convention center, and (4) food preparation waste from a restaurant. Each sample was tested in triplicate 8 L batch anaerobic digesters after shredding and after shredding plus grinding. Average methane yields for the university dining, grocery store, hotel, and restaurant wastes were 363, 427, 492, and 403 mL/dry g, respectively. Starch exhibited the most complete consumption and particle size did not significantly affect methane yields for any of the tested substrates. Lipids represented 59–70% of the methane potential of the fresh substrates.

1. Introduction

The U.S. EPA estimated that 251 million tons of municipal solid waste (MSW) were generated in the U.S. in 2012 and that over 50% of this waste was disposed in landfills (U.S. Environmental Protection Agency, 2014). As the quantity of materials that are recycled has increased, food waste has become the next logical waste component to target for diversion from landfills. Food waste is estimated to make up 14.6 and 21.1% of the MSW generated and discarded in the U.S., respectively, and it is both a rapidly degradable and high methane yield substrate. As food waste decomposes rapidly in a landfill, significant methane is produced prior to installation of the gas collection system. For example, using a decay rate of 0.14 yr^{-1}, as suggested by De la Cruz and Barlaz (2010), 24.6% of the methane potential of food waste would be produced in the first two years of decomposition, during which time a gas collection system is not required by the New Source Performance Standards or NSPS (40 CFR Part 60, 2011). Thus, food waste is a particularly appealing target for landfill diversion.

One alternative for food waste diversion is anaerobic digestion (AD). Currently, large scale AD is a viable option for organics diversion because biogas, a valuable energy source, is produced and the digestate can be used as a soil amendment, which may offset the addition of mineral fertilizers. AD has become a common practice in Europe due to waste directives requiring European Union Member States to reduce the quantity of organic waste disposed in landfills (European Environmental Agency, 2009). Recently, there have been several efforts to promote organics diversion from U.S. landfills. For example, in 2014, Massachusetts required businesses and institutions that dispose at least one ton of food per week to treat their waste through composting or AD, or to donate the unused food to charity or to farms for animal feed (Department of Environmental Protection, 2014). In California, the Greenhouse Gas Reduction Fund has allocated $19.5 million in grants to promote an increase in recycling and organics diversion (http://www.calrecycle.ca.gov/NewsRoom/2014/11Nov/27.htm, April 2015).

There have been numerous studies to measure the methane potential of food waste and measured methane yields range from 130 to 630 m^3/Mg volatile solids (VS) (Appendix Table A1). There are a number of factors that may explain this range including variation in the chemical composition of the food waste feedstock, particle size, reactor configuration, and the length of the digestion period.

Commercial food waste represents a desirable feedstock for AD because it is generated in large quantities at a few locations as opposed to residential food waste that is generated in smaller quantities at a large number of locations. In addition, it may be easier to reduce the presence of contaminants in commercial food waste due to the smaller number of waste generators and opportunities for employee training.

Currently, there is little information on the methane potential of commercial food waste from specific waste generators that represent likely suppliers of food waste to AD. The objective of this research was to characterize the methane yield and chemical

* Corresponding author.
E-mail address: barlaz@ncsu.edu (M.A. Barlaz).

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composition of commercial food waste from four sources including waste generated at a grocery store (G), university dining hall (U), hotel and convention center (H), and restaurant (R). A second objective was to determine the effect of particle size on CH_4 production. The anaerobic decomposition of food waste was characterized by measurement of the methane yield and chemical composition (starch, cellulose, hemicellulose, lignin, protein, and lipids) prior to and after decomposition.

2. Materials and methods

2.1. Experimental design

Four commercial food wastes were tested (G, U, H and R) in two particle sizes, shredded and pumpable (GS – grocery store shredded; GP – grocery store pumpable; US – university dining hall shredded; UP – university dining hall pumpable; HS – hotel and conference center shredded; HP – hotel and conference center pumpable; RS – restaurant shredded; and RP – restaurant pumpable). These wastes included both pre- and post-consumer food wastes. Each feedstock was characterized and digested in triplicate 8 L batch reactors after either shredding or shredding and then grinding to a slurry, to simulate systems in which the waste is pumped. Each reactor was filled with a 7:3 volumetric mixture of well-decomposed MSW inoculum and food waste to insure the stable onset of biodegradation (Wang et al., 1997). Reactors were incubated in a room maintained at 37 °C to enhance the rate of microbial biodegradation. Control reactors with MSW inoculum only were operated to measure background methane production from the MSW inoculum. Two sets of controls were initiated as the G and U reactors were initiated first, followed by the H and R reactors 3 months later. BS1 was the control treatment for G and U, while BS2 was the control treatment for H and R reactors. Each reactor was operated until methane production was either no longer measurable or the methane yield had changed by less than 1% over the previous 3 weeks.

2.2. Feedstock collection and inoculum preparation

Food waste was collected from waste generators that separate organics as part of their daily procedures. Approximately 40 L of grocery store waste was sampled from Weaver Street Market in Carrboro, NC. This waste was obtained on one weekday and was sourced from hot bar buffet food remains and discarded produce. Visually, this waste largely consisted of discarded vegetables and a mass of grits (ground corn) with French toast from the hot bar. University dining hall food waste was collected from NC State University's largest campus dining hall. Approximately 30 L of post-consumer dining hall waste was collected on four consecutive weekdays. By visual inspection, the waste mostly consisted of bread, meat, cheese, and fruit and vegetable waste. Approximately 30 L of hotel food waste was sampled from the Sheraton Imperial Hotel and Convention Center in Durham, NC. This sample was obtained on one weekday and consisted of pre- and post-consumer food from the kitchen. The majority of the waste consisted of large beef tenderloins, cheese, sour cream, and potato peels. The restaurant waste was collected from The Irregardless Café in Raleigh, NC. Approximately 30 L of food preparation waste was collected on three separate weekdays. The food preparation waste consisted mostly of discarded raw vegetables and raw meat with bone scraps.

Collected food wastes were frozen upon arrival in the laboratory prior to further preprocessing. Each frozen feedstock was shredded with a slow-speed, high-torque shredder (Shredpax AZ-7H). To achieve a slurry or pumpable material, part of the shredded feedstock was ground through a 0.5 cm diameter aperture meat grinder (Northern Industrial, Burnsville, MN). Once shredded or ground, samples were frozen until used for reactor loading. Anaerobically decomposed MSW was used as an inoculum to initiate decomposition. This MSW was obtained from a ~300-L reactor maintained in the Environmental Engineering Lab at NC State University.

2.3. Reactor construction and filling

Each reactor (Fig. 1) consisted of an 8-L polypropylene jar with an airtight screw cap (U.S. Plastics Corp., Lima, OH), a 2-L intravenous bag (Baxter Healthcare, Deerfield, IL) for leachate collection and recirculation, and two 25-L flexfoil gas collection bags (SKC Corp., Houston, TX). At reactor initiation, the well-decomposed MSW inoculum and the thawed food waste were mixed to reach a 7:3 volumetric mixture of inoculum to food waste (Wang et al., 1997). After adding the mixture to a reactor, the reactor was sealed and sparged with N_2 to remove any residual O_2. After the food waste moisture drained into the recirculation bags, sufficient deionized water was added to obtain approximately 500 mL of leachate. Reactors contained 350–500 dry g food waste.

2.4. Reactor operation and sampling

Reactors were operated to maximize the extent of decomposition. This included inoculation as described above, incubation in a room at 37 °C, and leachate neutralization and recirculation. Leachate was neutralized with 2 N NaOH every other day until a neutral pH range (6.8–7.8) was reached. Once neutral and methane production was initiated, leachate recirculation was reduced to weekly. Leachate samples were collected for chemical oxygen demand (COD) analysis weekly to biweekly. Soluble NH_3-N and PO_4-P concentrations were measured during reactor startup, near peak methane generation, and near reactor shutdown to ensure

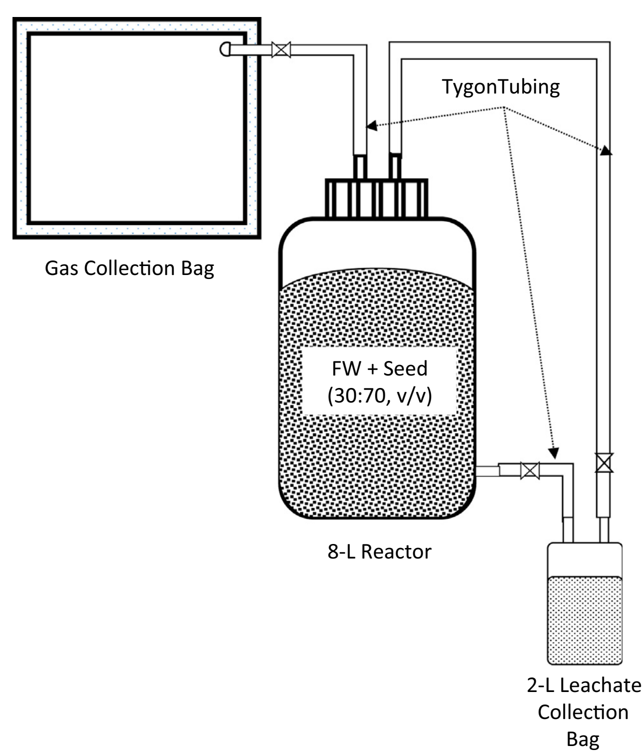

Fig. 1. Reactor configuration used for the anaerobic biodegradability testing of different food wastes samples (not to scale).