Food Waste – to – Energy: Teaching Students about Waste Disposal Options and the Science of Resource Recovery

Jan DeWaters, Clarkson University
Stefan Grimberg, Clarkson University

Faculty and students from Clarkson University (CU) are in the second year of a grant-funded partnership with a local K-12 school district to institute a school-wide resource recovery program and teach accompanying project-based lessons in selected science classrooms. With assistance from CU students and educational staff from the nearby Cornell Cooperative Extension Service (CCE), middle school (MS) and high school (HS) students at Canton Central School separate their cafeteria food waste (FW) into collection bins. The FW is transported to CCE's nearby Learning Farm, where it is processed in a small-scale anaerobic digester operated by CU faculty and students. Student ambassadors from the HS Environmental Club and MS Green Team work with the CU team to educate the student body about resource recovery, and encourage them to participate in the cafeteria FW collection program. The collaborative project intends to increase K-12 and CU students' knowledge and understanding of issues related to organic/FW management and options to create clean, renewable energy resources.

Like the majority of the general population, most students lack awareness of what happens to items they 'throw away'. Most don't know, and don't think about, where 'away' is. Exposing young people to best practices in waste management will help them develop lasting habits, and may also inspire them to share what they've learned with family and friends. Particularly when it comes to organics in the waste stream, and food in particular, our habits need changing. Americans discard 41 million tons of FW annually, making it the single largest fraction of material (22%) disposed in landfills in the U.S.[1] Sending FW to the landfill contributes to multiple pressing issues including gaseous emissions, leachate generation, and diminishing landfill capacity. Many states in the U.S. are in the process of revising waste disposal regulations to more closely control the disposal of organic wastes. New York State has mandated that as of 2022, facilities producing an annual average of at least 2 tons of FW per week will no longer be allowed to landfill their organic wastes.[2] Although the regulation does not apply to private residences, nursing homes, hospitals, primary and secondary schools, the village of Canton, NY, where our partner school is located, has proactively instituted a village-wide resource recovery program that allows Canton residents to drop off FW and later pick up compost for their yards and gardens. Residents bring their organic wastes to centrally-located collection bins, for treatment at the municipal compost site.[3] Clearly, the time is ripe for educating students about the importance of diverting organic materials from the solid waste stream!

Waste organics can be treated aerobically (i.e. compost) or anaerobically. While both produce valuable fertilizer, the biogas produced by anaerobic digestion contains approximately 60% methane and can be used in a variety of energy systems as a substitute for fossil fuels. Biogas produced by the anaerobic digester treating Canton Central School's FW is used to heat a small greenhouse where seedlings are started in early spring. Digestate, the liquid effluent from the digester, retains most of the nutrients and is used instead of commercial fertilizers at the Learning Farm. This process can be implemented in individual FW digesters, or as part of FW co-digestion at wastewater treatment plants or dairy manure digesters. Food waste is an energy-rich feedstock that, when added to municipal wastewater or dairy manure anaerobic digestion systems, increases energy production and improves process economics. This economic gain can be realized only if the costs for providing 'clean' waste, free of inorganic contaminants, are low. Thus the feedstock must be void of contamination that would require pretreatment to separate non-biodegradable substances (e.g. plastics, metals, glass) prior to being added to the anaerobic digestion system.

Diverting FW from the waste stream on a large scale requires a *cultural shift* so that organic waste streams of high enough quality can be generated. Our experience with educating college students on the merits of FW separation indicates that it is difficult to "undo bad habits" even with extensive outreach efforts. It is well known that long term behavioral change originates in early experience.[4] Thus, exposing K-12 students to source separation will engage them in good practices before those bad habits develop. The underlying hypothesis of our project is that that the earlier we expose students to FW separation and resource recovery the more likely they will retain proper waste disposal habits, generating a feedstock suitable for anaerobic digestion. Thus, a successful K-12 source separation program will facilitate long-term resource recovery.

Project-based educational experiences have been developed to complement the cafeteria FW program, so that students can learn the science behind resource recovery and anaerobic digestion. Evidence has shown that project-based and place-based learning experiences enhance student motivation, engagement, and learning.[5] Open-ended projects challenge students to operate at the higher levels of Bloom's taxonomy, and students tend to be more engaged in the learning process because they see the relevance of what they are learning to their lives outside of school. The method deepens students' understanding of principles that link concepts together, and enhances students' ability to retain and apply knowledge.[6] The CU team developed and taught 2 science experiments whereby HS students built small anaerobic bioreactors using glass bottles and balloons or Tedlar gas sampling bags. Various organic FWs were added and students measured the variation in gas production as a function of organic substrate composition over time. Teachers in various classes adapted the lesson to meet class-specific learning objectives (for example, chemistry students worked out the stoichiometry of the anaerobic digestion reaction; environmental science students predicted potential biogas produced from a typical dairy farm and the resulting impact on electricity-related CO_2 emissions).

Results from a student survey indicate significant gains in students' knowledge about energy in general and resource recovery specifically, their knowledge about anaerobic digestion, and their willingness to talk with their families about proper FW disposal practices. Compared to their high school counterparts, middle school students were more committed to the program, and had a greater sense of self efficacy when it comes to being able to contribute toward solving issues related to energy and the environment.

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[1] *Why is Sustainable Management of Food Important?.* (2017). Retrieved 1/24/2020, from https://www.epa.gov/sustainable-management-food/sustainable-management-food-basics

[2] https://www.timesunion.com/news/article/New-York-aims-to-curb-food-waste-13769177.php

[3] https://cantonny.gov/wp-content/uploads/2019/04/food-compost-flyerFINAL.pdf

[4] Evans, G. W., Otto, S., & Kaiser, F. G. (2018). Childhood Origins of Young Adult Environmental Behavior. Psychological science, 29(5), 679-687.

[5] N. Capon and D. Kuhn, "What's so good about problem-based learning," Cognition and Instruction, vol. 22, no. 1, pp. 61-79, 2004.

[6] D. Gijbels, F. Dochy, P. Van den Bossche and M. Segers, "Effects of problem-based learning: A meta-analysis from the angle of assessment," Review of Educational Research, vol. 75, no. 1, pp. 27-61, 2005.