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Waste Not, Want Not

California researchers and technology developers are commercializing a process that treats solid organic wastes such as grass clippings, food scraps, food processing byproducts, crop residues and animal wastes, and converts the materials into biogas that can be used to generate electricity, heat and transportation fuel.

by Jessica Ebert

Each year, Americans generate more than 200 million tons of solid wastes. Although communities across the country are intensifying efforts to recycle elements of household trash, these programs generally work with the dry and easily separated materials like plastics, metals, glass and newsprint. More often than not, the wet, soggy and sometimes rotting organic portions of garbage such as food scraps and animal wastes are left to be hauled away to the landfill. For the past eight years, however, researchers at the University of California, Davis have been developing and fine-tuning a method for the anaerobic digestion of organic solid wastes and liquid wastes into compost and biogas for the generation of electricity, heat and transportation fuel.

"The new technology brings many benefits to the public, including improvement of environmental quality and public health and production of renewable energy," says Ruihong Zhang, the inventor of the new system and a professor of biological and agricultural engineering at UC-Davis. This is "an effective method for solving organic waste disposal problems through converting the waste into clean biogas fuel, compost and other valuable products," she adds.

Zhang, who has worked in the areas of animal waste treatment and wastewater treatment digesters for nearly 20 years, started thinking about anaerobic solid waste digestion after moving to UC-Davis in 1995. "I realized there was a lot of solid waste around like rice straw, for example, that had not been looked at much from a digestion and biogas conversion standpoint," Zhang explains. But at that time, "There was no efficient digester design available that would handle solid waste," she says. Although researchers attempted to tackle the solid waste digestion problem throughout the 1970s and 1980s, Zhang explains that their approach required an extensive pretreatment of the solids that included separation, particle size reduction and the addition of a lot of water. This turned the solid waste into a kind of wastewater pulp that could be handled with digesters designed for wastewater treatment.

An energy intensive pretreatment is a significant drawback, however, so reducing this was one of the criteria that Zhang aimed to meet with the design of her digester system. In addition to a low energy requirement for pretreatment, Zhang set out to conceive a process that could handle large particles of solid waste and process it more quickly and in smaller digesters than are used in typical wastewater systems. This process would reduce capital costs and the physical footprint of the system as well as destroy any pathogens associated with the waste, which would allow the digested residues to be used as organic fertilizers.

The innovation that meets these criteria has been in development for the past several years and is dubbed the anaerobic phased solids (APS) digester technology. "The APS digester technology has overcome the deficiencies of existing anaerobic technologies and has proven to be a much more efficient and versatile technology for treating a variety of organic wastes including both wet and dry materials," Zhang says.

The technology consists of two stages of digestion. In the first stage, a hydraulic piston pump pushes the solid waste into tanks colonized by a mixture of anaerobic bacteria that break down the solids to organic acids and hydrogen-rich biogas. The biogas stream that is extracted at this point in the process is a first for solid organic waste digestion. "There are no commercial systems right now that can produce hydrogen stably via biological reactions," she says. "This is the first commercial system to provide hydrogen production as well as methane production." The latter is generated in the second step after the organic acids from the first stage tanks are separated from the residual solids and transferred to a second-stage tank. Here the organic acids are transformed into methane gas by a specific group of anaerobic, methane-producing bacteria. After digestion, the residual solids are separated from liquid and removed for composting material while the remaining liquid is recycled and reused in the digester system.

The bacteria characteristic of both stages in the process are naturally occurring microbes that were initially isolated from existing sewage digesters, Zhang explains. The environmental and process conditions within the digestion tanks have been tested, tweaked and fine-tuned to achieve optimum growth of the bacteria, which favors the fast and efficient conversion of organic solid wastes.

The APS digester technology has been scaled up twice over the past eight years from its laboratory prototype. The latest iteration in this scale-up, the first commercial-size facility of its kind called the UC Davis Biogas Energy Project, has been operating on the school's campus since October 2006 with support from the California Energy Commission, the California Integrated Waste Management Board and UC-Davis, Onsite Power Systems Inc. and several other companies. "This plant has provided a platform for demonstrating the new technology and also to test larger quantities of organic waste," Zhang explains. The facility is 28,000 times bigger than the laboratory-scale technology with a materials handling system that can handle 60 tons of waste per day. The plant houses five-digester tanks sized to treat 8 tons of solid waste per day, which is sufficient for producing enough biogas to power 80 homes. "It's of a real size to show people who are interested in using the technology as well as giving us a research demonstration capability to test real materials and to get data to support commercial development," Zhang says.

This data, which are used to measure the technical performance of the technology, includes biogas production rate and yield, the composition of hydrogen and methane in the biogas, waste reduction, energy conversion efficiency and economic and environmental impact analyses. "The research results have proven that the APS digester is a more energy-efficient, cost-effective and environmentally friendly waste treatment technology, compared with existing waste conversion technologies," Zhang says. This includes composting and combustion, which are conventional, alternative technologies for managing organic solid wastes. However, the significant energy inputs required for composting and the air quality issues associated with the gases and particles emitted during combustion are drawbacks.

The Biogas Energy Project, on the other hand, demonstrates the steps involved in the feeding of solid wastes into sealed, emission-free tanks, the digestion of that waste and the collection of biogas generated in the two stages, the cleaning of the hydrogen and methane produced in the process and the use of that biogas in an engine generator to make electricity or a boiler for heat. "It's a complete demonstration system for waste-to-energy conversion," Zhang says.

Food scraps collected from cafeterias around campus and from several Bay Area restaurants were initially processed at the plant. After six months of testing, the facility was shut down and improvements made including increasing efficiency of the material handling equipment and insulation for the tanks. The goal of the biogas project is to show that the demonstration facility uses less than 20 percent of the energy it produces, which was an initial goal of the project, Zhang explains. The remaining energy can then be exported as a biogas energy product, she says. Currently, the plant is processing food waste from a Campbell Soup Co. manufacturing plant in Sacramento, Calif. "The demonstration plant has been running very well and continuously for biogas production," Zhang says.

Zhang and colleagues will continue to collect data on the processing of the soup waste, and plan to eventually test a mixture of corn waste and food waste and then green waste such as grass clippings. The researchers are also taking a closer look at the microbes involved in digesting the solid wastes and doing DNA sequence analyses to determine the major players in the process. The ultimate goal is to develop seed cultures of high performing microbes able to grow and maintain stable populations in commercial systems.

Meanwhile, Onsite Power Systems Inc., a privately held company that provided significant funding for the Biogas Energy Project and has licensed the technology from the university, is currently developing several commercial projects including a 250-ton-per-day system that would process a mixture of food and green waste for a local waste management company north of Los Angeles and a 30-ton-per-day system to process chicken waste from a local farm. "These exciting projects are already in the development phase," Zhang explains. "We've made excellent progress and we're very happy with what we have so far."

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