Steam reforming of animal biomass

R.R. Chandran[*a], R. Eylanbekov[a], M. Toma[a], R. Stephens[b]
[a]Manufacturing and Technology Conversion International, Inc.
6001 Chemical Road, Baltimore, Maryland, USA 21226
Fax: 410-354-0471; RChandran@mtcionline.net
[b]StoneChem, Baltimorel, MD, USA

The intensive production of poultry and livestock (billions of chickens and millions of cattle and pigs annually in the United States) has increased the generation of manure and aggravated the waste disposal problem. Animal waste management has become such a hot topic that two workshops have recently been held [1,2] to find solutions. The presentations included such technologies as combustion, gasification, cofiring and anaerobic digestion. Some key points from the two workshops are summarized below:

- Use the term "Animal Biomass" instead of "animal waste" to focus on the problem.
- More than 200 million tons of dry animal biomass (corresponds to about 1.4 billion tons of wet weight) is generated annually in the U.S. This corresponds to about 1.5 quads of energy and represents an important renewable energy source. In population equivalent basis, animal biomass is 25 times that of human waste.
- The challenge in utilizing animal biomass is to maximize profit while minimizing environmental impact - odor, water pollution, greenhouse gases, antibiotic, harmone, and pathogen release.
- There is a need to develop methods of concentrating key nutrients to permit economical transport.
- Systems to capture both the nutrient and energy components of animal biomass represent an opportunity to add value to the livestock and poultry operations. Systems must be readily usable on the farm, reliable and a support infrastructure must exist to maintain the equipment.

The key points cited above and the shortcomings of the commercially available treatment options presented a great opportunity for the application of steam reforming to manage and utilize animal biomass in a more efficient, cost-effective, and environmentally beneficial manner. A study was performed under a grant from the U.S. Department of Energy Small Business Innovation Program to develop a steam reformer based biopower system. The specific objectives of the research were to:

- Perform feedstock characterization tests and optimize process;
- Conduct market and resource assessment;
- Carry out a preliminary integrated system design;
- Estimate costs; and
- Perform technical, environmental and economic assessments.

A small laboratory-scale steam reformer test system was designed, fabricated and assembled. It comprised a steam generation subsystem, an electrically heated fluid bed, a screw feed subsystem, particulate filters and a gas analysis subsystem. The initial target feedstock was poultry manure. The objective of the feedstock characterization tests was to evaluate the performance and operability of the steam reforming system for processing poultry manure. Shakedown tests were first conducted to map out the preliminary performance and operational boundary. This exercise was intended to firm up the test plan and the test strategy. Tests were then performed in accordance with the test plan. Safety procedures were followed due to a potential for the formation of phosphine. Detection for phosphine was carried out. During the test, all process parameters were monitored and recorded. Two MTI Model M-200 gas chromatographs (GCs) were used for detailed quantitative analysis of the steam reformer product gases. Representative solid samples and condensate were collected and samples were sent to a reputed laboratory for analyses.

The feedstock characterization tests with poultry manure were performed at three different fluidized bed temperatures i.e. 1,100 F (593 C), 1,300 F (704 C) and 1,500 F (816 C). Phosphine was not detected during these tests. The carbon conversion improved with bed temperature. The data indicated that the steam reformer fluidized bed should operate at about 1,500 F (816 C) for superior performance. At this condition:

- The steam reformer demonstrated safe, stable and reliable operation.
- There were no operational problems such as agglomeration, defluidization, channeling or heater fouling.
- The carbon conversion was excellent (~99%).
- The product gas generated was rich in hydrogen (~55% by volume) and the higher heating value (HHV) was 322 Btu/dscf (12 MJ/m^3 dry). The product gas yield corresponded to 5,936 Btu/lb dry feed (13.8 MJ/kg of dry feed) or a product gas HHV to dry feed HHV ratio of 1.2.
- Practically all of the chlorine was released and a majority of the sulfur and the nitrogen were released as well.
- Traces of Volatile Organic Compounds (VOC) and Semi-Volatile Organic Compounds (SVOC) were detected in the gas condensate. The condensate VOC loading was 0.065 g/lb (0.14 g/kg) of dry poultry litter with benzene as the primary constituent. The SVOC were higher and corresponded to 1.54 g/lb (3.4 g/kg) dry feed with Naphthalene as the primary constituent. This result is attributed to the small test unit size, limited residence time, significant freeboard heat loss, etc. These species can be minimized in the condensate by careful and proper design of the reformer for commercial operation.
- Nitrogen mainly reported as NH3 in the gas phase while phosphorus and potassium showed up predominantly in the cyclone catch.

A nominal 77 kW biopower system was configured by integrating the PulseEnhanced steam reformer with a Northern Research and Engineering Corporation microturbine. Computer analyses indicated the net electrical efficiency to be 15.2% on lower heating value (LHV) basis, a fertilizer grade material production rate of about 1 ton per day and very low emissions (lower than one-tenth of New Source Performance Standards). An economic evaluation indicated that with technology maturity and appliance type mass production, electricity can be produced for a total cost of about five cents/kWh where the fuel has no cost or approximately nine cents/kWh for fuel costing $20/dry ton. These costs are competitive with costs of electricity to residential, commercial and even industrial consumers for much of the United States.

Steam reforming tests have recently been conducted with swine waste as well. The results were again very encouraging.

References

[1] Summary Report of the Workshop on Opportunities to Improve and Benefit from the Management of Animal Waste, coordinated by Sheffield J, Joint Institute for Energy & Environment, Knoxville, TN, Mar 24-26, 1999.
[2] Bonk D., Animal Waste Utilization Workshop; Proc. of the Animal Waste Utilization Workshop, Edited by Bose AC, U.S. Dept. of Energy, Federal Energy Technology Center, Morgantown, WV, June 8-9,1999.