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Co-Digestion of Dairy Manure and Food Processing Waste with Composting and Manure Injection

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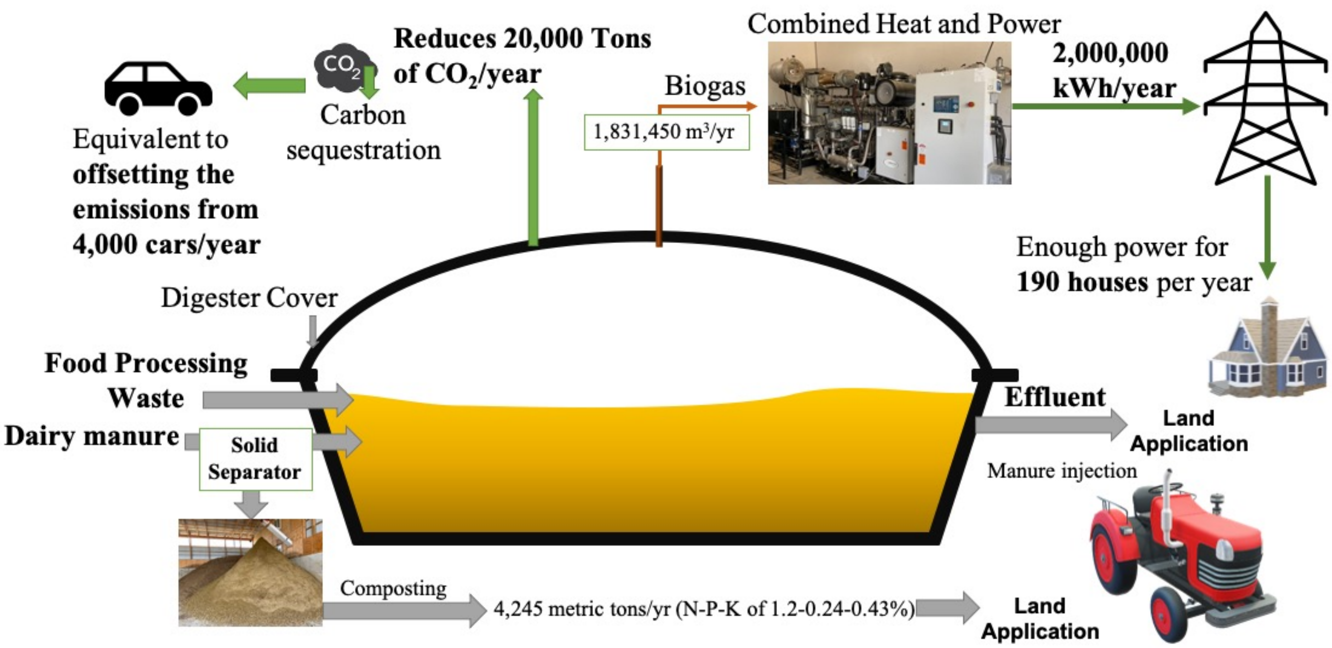
Case Study: Anaerobic Digestion of Dairy Manure and Food Processing Waste with Renewable Energy, Composting, and Manure Injection



Project Goal:
Transformations in nutrients, solids, and energy production were monitored over 13 months, with a life cycle assessment (LCA) of a farm-scale anaerobic digestion (AD) system that included composting and manure injection. Anaerobic digestion is a biological process that creates renewable energy in the form of biogas from substrates, such as manure, food waste, and wastewater sludge. The sustainability of anaerobic digestion, composting, and manure injection was quantified based on energy production and a LCA that quantified material and energy inputs and outputs. The biogas generated by the anaerobic digester was used directly to generate electricity and heat the digester. The solid separator removed solids from the dairy manure, with the solids composted to generate a value-added product.

Anaerobic Co-Digestion of Dairy Manure and Food Processing Wastes:
In this system, the liquid portion of the manure was separated (72% of the dairy manure volume) and digested, and the separated solids were composted. The liquid fraction of dairy manure has higher concentrations of the dissolved organics used for biogas conversion. The more fibrous solids take longer to decompose. Dairy manure can be digested with or without solid separation. Some AD systems use solid separation after digestion with the digested solids used for cattle bedding. In this system, sand bedding was used, with the sand separated from the manure waste stream in a gravity sand lane. The higher quantity of solids in the pre-digested manure was used for composting, and the liquid digester effluent was used for flushing the dairy barns.

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The food processing waste that was co-digested with the liquid dairy manure was the dissolved air flotation (DAF) portion of poultry processing waste, which has high concentrations of fats, oils, and grease, and cranberry processing waste, which has a high concentration of sugars.

System Components and Operational Process:
The dairy manure and food waste co-digestion and compost system process operated as follows:

1) Dairy manure and bedding material was washed from the barn onto a gravity-based sand separation lane.
2) Dairy manure was processed through a screw-press, followed by a vibrating solid separation unit to separate the solid and liquid fractions.
3) The dairy manure solids were transported to the composting facility via a conveyor belt.
4) The liquid manure was pumped to the digester.
5) Food processing waste, DAF and cranberry, was stored in two separate open containers and mixed before pumping into the digester and mixed with the liquid dairy manure.
6) The digester is mixed using recirculated digester contents that is heated externally from the captured heat of the combined heat and power (CHP) generator for electricity.
7) Prior to utilizing the biogas in the CHP, the biogas is scrubbed of hydrogen sulfide (H_2S) in an iron-based system to protect the generator form corrosion.
8) The digester effluent is stored in an open lagoon that is used both for flushing the lanes of the dairy barns and crop fertilization via surface application or manure injection.

Monitoring Results:
The farm-scale AD system processed 6,207,414 gallons of dairy manure per year, with an average energy production of 1,980,000 kWh/year, averaging 1,522,620 m^3 biogas/month (631 L CH_4/kg VS). The H_2S concentration averaged 212 ppm before the scrubber, and 4.4 ppm after the scrubber, which is well below the threshold for digestion. Throughout the monitoring period, 72.2% of the biogas was used for electricity generation, and 27.8% of the biogas was flared and not converted to renewable energy, as the generator was run near capacity. The generator processed 1,322,306 m^3 of biogas/year, producing and an average of 224 kW/hour of electricity.

The solids separator and filter press produced 4,703 m^3 of separated solids annually, generating 4,245 tons of compost that contained 1.2% N, 0.24% P, and 0.43% K.

Dragline manure injection and surface application were analyzed for ammonia (NH_3) volatilization. Manure injection had negligible ammonia (NH_3) lost to the atmosphere (below detection limit), while surface application reached a maximum of 16.4 mg NH_3-N/L 24 hours after application.

A biochemical methane potential (BMP) test was conducted with individual substrates and mixtures of DAF and cranberry co-digested with dairy manure. The results showed that dairy manure (no solid separation), DAF, and cranberry had the highest CH_4 efficiency (987 L CH_4 /kg VS), which was similar (958 L CH_4/kg VS) to the substrates used at Kilby Farm (liquid DM after solid separation, DAF, and cranberry). The lab-based efficiency was higher than on-farm results (631 L CH_4/kg VS), which is expected. The highest CH_4 was produced with mono-digestion of DAF and cranberry (922 mL CH_4 and 909 mL CH_4, receptively), which was slightly higher than Kilby Farm co-digestion (866 mL CH_4), with the differences between the on-farm and BMP results attributed to the ideal conditions of the of the lab-based batch conditions used in BMP digestion.

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Life Cycle Assessment (LCA)

The life cycle assessment (LCA) showed that the co-digestion and composting system at Kilby Farm lowered GHG emission by 81% (4,495 T CO_2 eq/year) and eutrophication by 447% compared to the Baseline Scenario of no anaerobic digestion and no composting with open lagoon manure storage (23,751 T CO_2 eq/year). Compared to digesting only dairy manure (no food processing waste included), there were small increases in fossil fuel depletion (3%) and ozone depletion (6%) due to the emissions associated with the transportation of food waste to the digester (DAF was 30 miles and cranberry waste was 100 miles). Additionally, using 100% of the biogas in a combined heat and power (CHP) generator would be more sustainable than flaring nearly 1/3 of the produced biogas due to the generator being operated near capacity. The LCA showed the positive impact of having digestion and composting on-farm, with large reductions in environmental impacts by adding a digester.

Lessons Learned

- The LCA showed that the current conditions at Kilby Farm was the most effective in mitigating emissions in 8 out of 10 environmental impact categories.
- The biogas used in a CHP generated a net positive energy production, producing nearly 2,000,000 kWh/year.
- The hydrogen sulfide (H_2S) scrubbing system was near 100% efficiency for the entirety of the monitoring period, eliminating corrosion in the CHP.
- The lab-based BMP analysis showed that co-digesting DAF, cranberry, and liquid DM produced high levels of cumulative CH_4 and high bioenergy conversion efficiency, which was near to the actual on-farm CH_4 production.

Conclusions

A farm-scale anaerobic digestion system was evaluated for anaerobic digestion and compost production. Over 13 months, monthly samples were collected from nine sampling points to verify the system performance. The results showed that using anaerobic digestion to convert the dairy manure and food processing waste to biogas and compost is possible in Maryland. The total biogas production was 1,831,450 m^3/yr from the system which generated 1,983,711 kWh/yr, with 4,245 metric tons of compost produced to be used as fertilizer. The life cycle assessment (LCA) showed that current operation had large decreases in environmental impacts, especially greenhouse gas emissions and eutrophication. Lowering transportation distances of the food processing waste would further increase sustainability.

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