On-Site Evaluation of Food Processing Waste Using Dry Digestion

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Final Report

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Project Background

The most recent Wisconsin municipal waste composition study conducted in 2009 reported food waste was approximately 50% of the total organic waste generated or 455,259 tons annually (Recycling Connections Corporation & MSW Consultants 2010). In addition, food processing waste from the Wisconsin vegetable industry is abundant increasing the total waste produced from these two sources. While household food waste is produced year round, vegetable processing waste in Wisconsin is limited to harvest and processing periods (late spring through fall) and can be highly variable in terms of production timing and characteristics. The vegetable processing by-product streams are also highly degradable and subject to quick spoilage requiring immediate disposal (land application) or storage (ensiling) for animal feed. The current disposal methods are costly to vegetable processing facilities and commonly do not utilize the by-product components to their maximum potential or value.

Current disposal methods include land application and landfilling at a cost of $10-$50 per ton, totaling tens of millions of dollars annually. These applications consume large land resources, produce significant atmospheric greenhouse gas emissions (almost 2 million tons CO₂ equivalents per year {CO₂e/yr} when landfilled; Baldano and Soriano 2000), odor, and contaminate waterways through leaching and runoff. Anaerobic digestion is one technology that can be used to reduce the impact of emissions of these waste products (by capturing methane and converting to carbon dioxide through combustion) while producing a revenue stream from the sale of the energy produced or a decrease in operating costs if the energy is used on-site. However, current construction costs of anaerobic digestion systems have limited installation within Wisconsin as many times the revenues or avoided costs do not cover operating costs. Lack of research into feedstocks, operation, and economic optimization has left this potential waste-to-energy technology underused and underdeveloped within North America for many waste streams including food processing facilities.

It is critical for technologies, such as anaerobic digestion among others, to be investigated for incorporation at vegetable processing facilities. As these types of facilities produce a large volume of biomass at a central location there is great potential to reduce environmental impacts and increase sustainability throughout the vegetable production process.

Objectives

Dry anaerobic digestion (AD) is an alternative waste treatment/disposal method which anaerobically degrades solid waste to produce biogas. Implementation of dry digestion systems in the United States has been limited due to lack of information on biogas production potential. Specific feedstocks require analysis to determine the biogas production potential. The specific objectives of this research are to:

1. Design and implement a mobile dry digestion system for site specific feedstock evaluation
2. Evaluate the inoculum ratio of digested manure to sweet corn and green bean waste needed for anaerobic digester start-up
3. Evaluate the biogas production potential of green beans and sweet corn canning by-products from a vegetable production facility
4. Determine the biogas production potential of sweet corn which is stored prior to digestion
Methods and Materials

System Design

To evaluate the above objectives a pilot-scale trailer digestion system was developed, Figure 1. The portable system has three 208 liter dry digestion systems (operated with wastes at greater than 15% total solids content or less that 85% moisture), Figure 2. These are batch systems in which the waste is mixed with inoculum, added to the tank, and then sealed. Each tank is conical in shape at the bottom with a grate at the bottom to allow for collection of leachate produced in the conical portion.

Temperature consistency is critical for maintaining biogas production and reducing variability in degradation rates. The pH within the digester can indicate the process rates and alert the operator to conditions (particularly acid build-up resulting in low pH) that require action to rectify and maintain the system. The digestion tanks were equipped with heating bands which were placed on the outside of the
tanks to transfer heat to the digestion systems. The heating bands were set to maintain mesophilic temperatures of approximately 38 degrees C (variations in temperature are provided in the results section). Fiberglass insulation placed over the heating bands was used to reduce the energy needed to maintain the temperature in the digesters. Each digester was equipped with semi-continuous read sensors, three temperature sensors and one pH sensor connected to a data acquisition system that includes a Campbell Scientific data logger connected to a laptop computer.

Gas ports on the top of the digesters allowed for the collection of biogas in Tedlar bags. The volume of biogas produced from each digester was then measured using a water displacement gas meter to quantify production. A small fraction of the biogas was transported to the UW-Madison labs to determine the biogas quality by evaluating the methane content.

All system components have been loaded onto a small open trailer with a transportable canopy to protect the digestion systems from precipitation (the sides of the canopy are removable to prevent development of a confined space where gases could potentially be trapped), Figure 3.

![Figure 3: Pilot-scale trailer system and canopy](image)

**Research Site**

Del Monte operates a plant in Cambria, WI which processes green beans, peas, and sweet corn for canning. This plant is highly automated producing a variety of segregated waste streams from early summer (June) to late fall (October). Fifty to sixty tons of green beans are processed per day for a 75 day period, one truckload of peas per day for 25 days, and 600 tons per day of corn for 60 days all within this processing period. During processing, solid waste consisting of foreign objects (organic and inorganic), blemished or damaged vegetables, and unusable vegetable pieces are sorted and transported to trucking containers for disposal. Currently the solid waste produced from the processing of these vegetables is land applied or ensiled at existing off-site locations for animal feed. Wastewater produced during vegetable processing is routed and stored in a holding pond for disposal using land application. All wastes are currently disposed of at a cost to the processing facility (however this cost was not tracked at the facility).

Certain aspects to this operation make it an ideal site for a waste-to-energy technology. Vegetable processing facilities have high energy needs that coincide with their waste production schedule making
it an ideal fit. The facility has use for electricity, gas for the boilers, and high grade heat. However, information is needed to provide data to be used to determine economic feasibility, include biogas production potential to determine potential revenues.

In order to assess the potential for the implementation of waste management strategies and technologies on food processing facilities this plant would be an ideal candidate to serve as a pilot facility to develop a strategy for evaluating waste handling/processing/treatment for vegetable production waste. The pilot-trailer system was transported and set-up on-site to evaluate green bean and sweet corn biogas production potential, Figure 4.

![On-site installation of the dry digestion system](image)

**Figure 4: On-site installation of the dry digestion system**

**Operation**

For each digester the top is removed and feedstocks (sweet corn and green beans) and inoculum (digested manure) are weighed and added with buckets. The inoculum ratio has been reported for many studies and varies based on feedstocks. For these studies we examined inoculum additions of 25% and greater as cited by literature (see details below). Following the addition of feedstocks the system is then sealed to eliminate exposure to oxygen. Microorganisms within the manure degrade the biological materials producing biogas, which is collected in Tedlar bags for volume and constituent analysis. Prior to installation at the site the system was evaluated to reduce the trouble shooting measures required on-site. The tanks were filled with water to assess any leaks and sensors were verified and calibrated to ensure the readings were accurate. Following the initial leak testing and calibration four phases of data collection was completed, details for each collection phase are below.

**Phase 1**

The first phase of the project period consisted of a combination of sweet corn, green beans, and digested manure, Table 1. The digested manure was added after the other feedstocks were weighed, blended, and fed into the system. Digested manure was added at a rate of approximately 35% of the total mass (feedstock plus inoculum). For phase 1 the digesters were operated and data was collected for 15 days.
Table 1: Mass of feedstock and inoculum added for phase 1

<table>
<thead>
<tr>
<th>Digester</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet Corn (kg)</td>
<td>67.5</td>
<td>52.5</td>
<td>53.9</td>
</tr>
<tr>
<td>Green Bean (kg)</td>
<td>0</td>
<td>17.0</td>
<td>15.8</td>
</tr>
<tr>
<td>Digested Manure (kg)</td>
<td>37.3</td>
<td>37.3</td>
<td>37.3</td>
</tr>
</tbody>
</table>

Phase 2

The second phase evaluated only two digesters and had feedstocks of sweet corn and digested manure only as the green bean processing at the canning facility was complete. Additional digested manure inoculum was added for this run, Table 2, and was again added following the sweet corn at an increased rate of 57% of the total mass added to the digester. The trial was conducted for 24 days.

Table 2: Mass of feedstock and inoculum added for phase 2

<table>
<thead>
<tr>
<th>Digester</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Sweet Corn (kg)</td>
<td>69</td>
<td>70</td>
</tr>
<tr>
<td>Digested Manure (kg)</td>
<td>93.4</td>
<td>93.4</td>
</tr>
</tbody>
</table>

Phase 3

The third phase of the testing was conducted on green bean waste only. The digested manure inoculum was added at a rate of approximately 30% of the total mass, but unlike the first two phases was mixed with the green bean processing waste as it was added to the digester, Table 3. The third data collection phase was operated for 50 days.

Table 3: Mass of feedstock and inoculum added for phase 3

<table>
<thead>
<tr>
<th>Digester</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet Corn (kg)</td>
<td>84.25</td>
<td>85.95</td>
<td>85.96</td>
</tr>
<tr>
<td>Digested Manure (kg)</td>
<td>36.8</td>
<td>35.5</td>
<td>36.45</td>
</tr>
</tbody>
</table>

Phase 4

The fourth and final phase was designed to determine the impact of storage on the biogas production from sweet corn processing waste. Sweet corn processing waste was collected from the Del Monte facility; half of the sweet corn was mixed with inoculum and added directly to the digesters. The second half of the sweet corn was stored in barrels for 40 days and then mixed with inoculum at the same rate and added to the digesters. Digested manure inoculum for each phase was added at a rate of approximately 40% of the total mass added to each digester. Phase 4 digestion data collections for fresh and stored corn were both conducted over 28 days.
Table 4: Mass of feedstock and inoculum added for phase 4

<table>
<thead>
<tr>
<th></th>
<th>Fresh Sweet Corn</th>
<th>Stored Sweet Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digester</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Sweet Corn (kg)</td>
<td>57.95</td>
<td>56.15</td>
</tr>
<tr>
<td></td>
<td>59.60</td>
<td>58.65</td>
</tr>
<tr>
<td>Digested Manure (kg)</td>
<td>43.1</td>
<td>41.7</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>35.5</td>
</tr>
</tbody>
</table>

Results

The first research phase of the project resulted in no biogas production for any of the three digesters. Temperatures remained mesophilic for the duration of the run, however the pH was extremely low resulting in conditions that do not support methanogens. Figures 5 & 6 show an example of one of the digesters performance over this time. Figure 6 shows a decrease in pH starting from day one indicating a production of acids which reduced the pH to nearly 4 for the remainder of the trial.

Figure 5: Phase 1 temperature of digester 1
For phase 2 the digested manure inoculum was increased from 30% to 57% of the total mass in an attempt to buffer the mixture during degradation and increase the overall pH. The increased digested manure however resulted in little biogas production over the course of the trial. Data recorded again showed similar finding as above with the pH reading consistently around 4 as above. The system was deconstructed and it was found that the manure was not effectively infiltrating the vegetable processing waste.

For the third phase of the project the feedstocks were mixed with the inoculum during filling. Although the inoculum rate was again reduced to 30% of the total mass, the digesters were able to produce biogas, Figure 7. The Tedlar biogas storage bags in digester 2 were found to have leaks so the data did not meet quality controls and is not represented. The increased biogas production indicated that an inoculum ratio of 30% of digested manure mass to total mass was suitable for start-up of the digestion system when using sweet corn.
The resulting biogas production for sweet corn increased for approximately 40-45 days where it then plateaued. The biogas production rate for sweet corn was calculated to be 2.5 (digester 3) to 5.0 (digester 1) cubic meters of biogas per metric ton. The average methane percentage was 41% and 47% for digester 1 and digester 3, respectively. This results in an average methane production of 1.9 (digester 1) and 2.1 (digester 3) cubic meters of methane per metric ton of sweet corn. This is much lower than that of other reported vegetables, but this is expected as much of the waste produced from the processing facility contains large volumes of water and it is harder to degrade plant material found in the by-products as compared to the vegetable itself. However, this also indicates that increased optimizations may increase biogas production of these vegetable processing wastes.

It was also found that the pH sensors fouled during phase 3. Although these sensors are made to be robust, it appears the conditions within the digester (particularly in phase 1 & 2) were corrosive enough to cause damage to the sensors.

Temperature sensors (3 in each digester) indicated that the temperature near the top of the digester (location 1) fluctuated with the ambient temperature, Figure 8. It also appears that fluctuations in temperature within the other two lower locations in the digester occurred for the first 10-15 days and followed the same trends within an individual digester.

![Figure 7: Phase 3 Biogas Production Rate](image-url)
Figure 8: Phase 3 Digester Temperature

Phase 4 was conducted to determine if it would be possible to compact and store the waste (as we ensile many animal feeds) to potentially reduce the size of the digester and have continuous biogas production throughout the year (outside the seasonal production period). Again there were fouling issues with the pH sensors and issues with the Tedlar biogas bags during measurement of the biogas. Fortunately, digester 1 and 3 which received raw corn waste directly after production and digester 2 which received the stored corn had viable data for comparison. It was found that storage of the feedstocks did not decrease the biogas production potential of the feedstocks, but actually increased production as compared to that which was used directly after sweet corn processing, Table 5. This may indicate that there is potential to store vegetable processing waste for biogas production on-site or for storage off-site to be added to other digesters such as manure based digesters. It also suggests that the increased inoculum of 40% may result in increased biogas production in comparison to that of phase 3 with 30% inoculum.
Table 5: Biogas production with and without storage of sweet corn processing waste

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Raw Corn Waste</th>
<th>Stored Corn Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digester</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Biogas Production (L)</td>
<td>780</td>
<td>690</td>
</tr>
<tr>
<td>Biogas Production (m3/ton)</td>
<td>13</td>
<td>12</td>
</tr>
</tbody>
</table>

Conclusions and Future Work

Vegetable processing waste is a viable option to produce biogas, however it may take significant work to optimize the system particularly for start-up. This work indicates that increasing from 30% to 40% of inoculum during start-up increases the biogas production potential. As batch systems require frequent start-ups, these parameters have much more impact that a continuously operated systems. It is also critical to achieve a blend of the feedstocks before adding to the dry digestion system as evidence by the initial application of liquid digested manure to the top of the feedstocks in the digester. The data collected in this study also indicates that storing vegetable processing waste may not have an impact of biogas production and may be a viable option for some who wish to add this type of waste to their digester throughout the year. Dry digestion systems may also have issues with heat stabilization and may require more effort to ensure the digester has a consistent temperature throughout than liquid systems which transport heat to the feedstocks more evenly.

Although this work begins to indicate some trends in the dry digestion of vegetable processing waste, additional work is needed to evaluate this information in greater detail. It would be valuable to complete the studies again with more replicates to complete statistical analyses for comparison.

In terms of the work at the Del Monte facility, the next steps are to start to track the waste production at the facility to begin to understand the annual biogas potential and complete a feasibility study. More robust pH sensors need to be designed and evaluated in order to collect value operational data.

For this specific site, the company has additional limitations including a minimum return on investment of < 4 years. In addition Del Monte like many other companies is concerned that this level of waste management is outside the mission of the company. Continued evaluation may prove to provide the necessary data that will make companies realize the potential to reduce costs associated with their waste and incentivize them to expand their scope. Alternatively, profitable feasibility studies may push investors to implement and run digesters at or near feedstock production sites.

References
