Comparison of Compost Efficiency of Digestate
to Undigested Organic Waste from a Dry Anaerobic Digester

February 2014

Student Investigator: Brooke Koenig
Advisor: Dr. Greg Kleinheinz

University of Wisconsin-Oshkosh
Abstract

In the fall of 2011, UW-Oshkosh began the construction on the first dry anaerobic digester (AD) in North and South America. At the facility, organic waste is utilized to produce a biogas that is high in methane. The organic waste is retained in each fermentation bay for a 28 day cycle, during which biogas is collected and used to power a combined heat and power (CHP) unit. At the end of a 28 day cycle, a fermenter is opened and all the material that has been digested, called digestate, is removed. In order for dry AD’s to be successful throughout America, research needs to be conducted to give scientific evidence on the uses of the digestate to help create other avenues of profit. This project therefore investigated the use of the digestate in composting compared to using organic material that was not processed through a dry AD system.

Statement of Objectives

The primary objective of this study was to determine if digestate is suitable for composting. The main purpose of anaerobic digestion is to generate energy from waste material, leaving a product at the end that is a low value product. By composting, digestate could be made into a product with a higher monetary value and more easily utilized by end users. From the new feedstock mixture of one batch and the digestate of that same batch 28 days later, each will be put into windrows where various parameters and chemical data will be taken during the composting process.
Introduction

The German based company BIOferm™ partnered with UW-Oshkosh to construct a high solids “dry” anaerobic digester (AD), Figure 1A. Although there are many liquid digesters across the nation, often found on large scale dairy farms to help deal with the high volume of bovine manure or at wastewater treatment facilities in larger cities, dry AD systems that deal with solid organic material are rare in the US. So what is a dry AD system, exactly? Dry AD differs from liquid AD by requiring a minimum of 20% dry matter (DM): this makes the material stackable. The concept is the same as that of the liquid predecessor’s – organic waste is biologically transformed into other forms, all in the absence of oxygen at mesophilic temperatures. One of these “other forms,” methane, is usually the product of interest in these anaerobic digestion reactors.

Over the course of a week, organic material is gathered in large quantities so that by the time a fermenter change needs to occur, nearly 150 tons of new material is loaded in. This material consists of bedding waste from local farms, yard waste from the city of Oshkosh such as grass clippings, and food waste such as that which is thrown away by
supermarkets as seen in Figure 2. All of this is mixed with material from the previous batch and placed into the fermentation bay, Figure 2C, where anaerobic digestion takes place over a 28 day cycle. At the end of the fermentation cycle, the material that is removed is called digestate. Currently, there are few peer reviewed research papers from the U.S. on the areas of use for digestate generated by dry AD systems.

Figure 2: A) Yard waste feedstock; B) Food waste feedstock; C) Digestate
With the establishment of a dry anaerobic digester at UW-Oshkosh, campus researchers have the unique opportunity to explore potential uses for the digestate that can in turn bring another source of revenue into the operation, an aspect that will be pivotal if dry AD systems are to be successful throughout the nation.

**Materials and Methods**

*Characterization of digestate and undigested organic mix used for the study:*

This task focused on determining the chemical and physical parameters of the digestate used in the digestate based windrow for this study. Specific tests included: determination of dry matter (DM) and organic dry matter (oDM), pH, total phosphorus (TP), temperature (T), bulk density (BD), and carbon dioxide and ammonia levels (CO$_2$ and NH$_3$). Measuring these parameters will help in elucidating how efficient further composting is on undigested organic feedstock mix and digestate to determine the benefits to further using digestate.

- **Dry Matter:** Following standard method DIN: EN 12880, this test determines what percent of the digestate is composed of water and how much of the material is solid. A weighed amount of digestate was placed in an incubator set to 105°C for a period of at least 24 hours. After 24 hours, the digestate was removed from the incubator, weighed, and returned to the incubator. The digestate was then weighed again 2 hours later to determine whether or not there was a change in mass. If the mass did not change, then the mass of the sample will be recorded.

- **Organic Dry Matter:** Following standard method DIN: EN 12879, this test determines what percent of the digestate is composed of organic material. Dried
digestate from the total solids method was placed in a muffle oven set at 550°C for at least 4 hours. After cooling in a desiccator, the sample was weighed. The resulting residue was composed of inorganic material.

- **Total Phosphorus:** Following standard method SM 4500-P F 20ed, digestate ashed in the volatile solids method was put through Standard Method 4500 P B5. In this method, the sample is digested using heat, sulfuric acid, and ammonium peroxydisulfate. After digestion, total phosphorus was measured colorimetrically using an ascorbic acid/ammonium molybdate reagent and a spectrophotometer. The resulting absorbance was measured against an established standard curve to determine the final concentration of phosphorus.

- **pH:** pH was measured using a standard calibrated ion-selective electrode following standard method DIN: EN 12176.

- **Bulk density:** Bulk density was determined with a sample of the undigested feedstock mix and the digestate that was put into windrows. The weight per unit volume of sample was calculated.

**Determine quality and efficiency of the composting process of digestate and undigested feedstock mix from the same batch**

This task took place over a 120 day period in which a windrow was constructed using A) 100% digestate from a 28 day cycle, B) a 50:50 mixture of food and yard waste, and C) a 25:25:50 mixture of food, yard, and digestate, Figure 3. These mixtures were then used to create windrows at the composting site, Figure 4. Windrow samples were collected on days 0, 30, 60, 90, and 120, and the sample was collected from three locations on the
windrows: right, center, and left. The following parameters were collected from each sample as described in Task 1 above, including the following:

- **Temperature:** Using a field probe, temperature was taken at each of the sample locations from all windrows.

- **Carbon dioxide and ammonia levels:** Using a Solvita Digital Color Reader (Woods End®), CO₂ and NH₃ levels were recorded at each of the three sample locations of both windrows before and after turning.

Figure 3: Initial piles mixed at digester. A) 100% digestate; B) 50:50 food and yard waste by weight; C) 25:25:50 food, yard, and digestate

Figure 4: Initial windrows made at compost site. A) 100% digestate; B) 50:50 food and yard waste; C) 25:25:50 food, yard, and digestate; D) Taking initial samples and parameters.
Summarize the data from using digestate material from a dry AD system versus undigested feedstock mix, representing organic waste, in a composting study.

As stated in the materials and methods, each windrow was sampled for lab analysis at the start and end of the 120 day sampling plan. Actual lab data is indicated in Table 1. This data was made into six graphs, Figure 5, representing each pre and post lab tests. These graphs allow for a visual representation of the lab data obtained for Table 1, and also allows for visual comparison between individual windrows and within each windrow. For example, Figure 5 A – C compare the initial and final dry matter content of each windrow, Figure 5 D – F compare the initial and final organic dry matter of each windrow, and Figure 5 G-I compare the initial and final total phosphorous in each windrow. The pattern looks constant between the windrows, however Figure 5 G is the most revealing. Windrow 1 was constructed of 100% digestate, and shows the highest total phosphorous for the initial value compared to Windrow 2 and 3. Phosphorous is an integral part of soil amendments, and the fact that there is more available at the start of the composting process when using digestate for composting indicates that digestate offers a starting material much more nutrient rich than raw, undigested organic material. Although Windrow 2, consisting of 50:50 food and yard by weight, contained a higher final amount of total phosphorous, Windrow 1 contained the second highest amount of phosphorous. In Figure 5 D – F, Windrow 1 indicates that digestate still follows the pattern of composting in a decrease of organic dry matter over time.
Table 1: The lab data from the initial and final lab tests run on each windrow.

<table>
<thead>
<tr>
<th>Samples</th>
<th>pH</th>
<th>DM%</th>
<th>oDM%</th>
<th>P (mg/Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windrow 1</td>
<td>Day 1</td>
<td>8.63</td>
<td>27.91</td>
<td>46.93</td>
</tr>
<tr>
<td></td>
<td>Day 120</td>
<td>8.68</td>
<td>57.91</td>
<td>25.91</td>
</tr>
<tr>
<td>Windrow 2</td>
<td>Day 1</td>
<td>4.67</td>
<td>24.7</td>
<td>88.67</td>
</tr>
<tr>
<td></td>
<td>Day 120</td>
<td>8.64</td>
<td>79.83</td>
<td>38</td>
</tr>
<tr>
<td>Windrow 3</td>
<td>Day 1</td>
<td>6.14</td>
<td>25.75</td>
<td>71.41</td>
</tr>
<tr>
<td></td>
<td>Day 120</td>
<td>8.54</td>
<td>58.19</td>
<td>61.68</td>
</tr>
</tbody>
</table>

Figure 5: Graphs representing initial and final data from windrow samples of DM, oDM, and total P.

The Solvita Digital Color Reader designed by Woods End® shows how compost is maturing over time and indicates how much attention the compost needs. For
instance, compost in a “Raw Compost” or “Active” state needs intensive oversight and management because the microorganisms are undergoing a high-respiration rate that requires a lot of oxygen. The compost can become “volatile” in these stages, in which case microbial processes could become damaged or hindered if proper management is not maintained. There were limitations in this project when working with the UW Oshkosh digester’s composting partner who operates a low budget composting site. Due to the distance from Oshkosh, it was difficult to have constant supervision over the management of the windrows, and therefore the composting process was subject to the standards the composting business used at their composting site. “Cured” or “Finished Compost” according to the Solvita Digital Color Reader indicated that compost was inactive, like soil, with no limitations for usage as a soil amendment. Figure 6 A – C shows the maturity index over time. Windrow 1, consisting completely of digestate, shows the best curve for compost moving from “Very Active” to “Finished Compost” over time, and also each a cured or finished state the fastest.
Figure 6: Graphs representing the maturity index by the Solvita Digital Color Reader.

By using the Solvita Digital Color Reader, the CO2 respiration in the compost could be monitored, as well as the amount of volatile nitrogen, as indicated by Figure 7 and Figure 8. These values indicate how volatile the compost is, and how much management is needed in terms of windrow turning to introduce more oxygen for the bacteria, and moisture addition if possible.

Temperatures were taken as stated above on the official sampling days, and the results are shown in figure 9. There does not seem to be an overly significant difference in the observed temperatures between the various piles. However the highest temperature spike was observed on day 30 from pile 2.
Figure 7: Graphs representing the CO2 respiration rate as indicated by the Solvita Digital Color Reader.
Figure 8: Graphs representing the volatile nitrogen as indicated by the Solvita Digital Color Reader.

Figure 9: Temperatures taken of each three composting windrows over time.
Figure 10: A) Initial windrow of 100% digestate; B) Initial windrow of 50% food waste, 50% yard waste; C) Initial windrow of 25% food waste, 25% yard waste, 50% digestate; E – G) The final windrows in pile form at the end of the 120 day composting research period; H – J) The condition of the material within the final composting piles.

Figure 10 visually shows the state of the windrows at the beginning of the research project and at the final sampling day, day 0 and 120 respectively. Figure 10 A – B are the initial windrows that were built on day 0. Figure 10 E – G are the final states of the compost windrows, which were piled due to the loss of windrow size during the course of the composting timeframe. Each pile in Figure 10 E – G has several
locations where a shovel was used to dig into the pile in order to collect the samples for the final lab work. Figure 10 H – J then shows what the material of the piles looked like, as it appeared very similar to finished topsoil.

**Discussion**

A repeat of this experiment could be conducted, one in where the mixture ratio’s are made by volume instead of by weight of the materials. For instance, a 50:50 mixture of food waste and yard waste would be built by using the same amount of front loader buckets for each waste type. Overall, it does appear that digestate is a good source of composting material, and that composting the digestate could potentially increase the value of this end product from anaerobic digestion. Coupling a composting process with a Dry AD facility would be very beneficial to future owner/operators. The trucking costs to haul digestate to the composting facility would be eliminated. Most importantly, you are first able to partially brake down the organic material during the AD process (21 - 28 day cycle) and extract renewable energy (in the form of methane gas) that would otherwise be lost if material went straight to aerobic composting. Then the final digestate can be further processed through a quick composting cycle to provide consumers with a higher value and more readily usable end product (fertilizer, soil amendment, etc.) than if it was not composted.