ANAEROBIC DIGESTION OF BIOBASED PLASTICS

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UW-Platteville and Underwriter Laboratories-Environmental along with the Wisconsin State Energy Office entered into an agreement over the summer of 2010 to carry out an analysis of biobased plastics at the benchtop and pilot scale level. Telles also served in an advisory role during this study. The goal was to determine if biobased plastics that have been shown under ASTM procedures (ATSM 6400) to be compostable could also be anaerobically digested. If the plastic can be shown to be digestible, it could lead to a large shift in food waste being diverted from landfills in the near future. This study carried the analysis one step further than by not only doing benchtop analysis, but also performing the analysis at the pilot scale level.

EXPERIMENTAL

The benchtop studies were carried out using a Bioprocess Control AMPTS unit. The procedure was altered from the standard ASTM 5511 test to better reflect actual dairy farm anaerobic digester conditions. The procedure mixed 300 ml of seed stock (digested manure) with 30 ml of a micronutrient buffer similar to the ASTM 5511 buffer solution providing 10% of the micronutrients in the ASTM procedure. Then 2 – 9 grams of the plastic to be tested was added to the bottle. Each test was done in triplicate along with a blank, negative (polyethylene), and positive (paper/cellulose) control. The analysis was then performed for 28 days to determine the total methane potential of each sample.

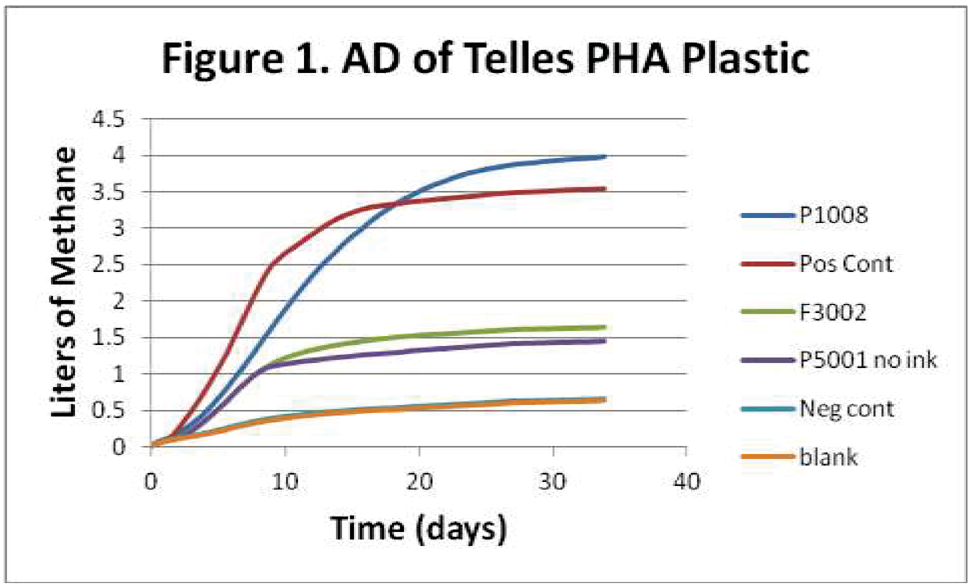
The pilot scale analysis was carried out using a trailer manufactured by Duane Hanusa of Baraboo, WI. This digester consisted of four 70 gallon tanks with individual temperature controls, a time controlled injection pump and a chopper pump. The tanks were filled to the 50 gallon level with about 20 gallons of gas space at the top. Each tank was heated individually. The procedure was to take 5 gallons of manure, add 5 gallons of water, run it through the chopper pump for 3-5 mins, and then place these 10 gallons in the tub with the injection pump. The injection pump was set up to inject for 6 seconds every 160 mins, so that within 24 hours, all of the manure mix would be added. The next day, a gas reading would be taken and then 10 gallons would be drained out and the process repeated. The gas monitoring unit consisted of a weighted flow meter that measured between 0.0 and 5.0 ft^3/hr of total gas flow. The digester was run at mesophilic conditions of 35 °C, as 95% of dairy digesters are run at the temperature of ~100 F.

Initially the pilot scale digester was started in the middle of September with 5 gallons of seed stock from a DVO (was GHD) digester and 195 gallons of manure from the dairy barn flush pit. To replicate the barns flush pit, 5 gallons of manure was collected from an aisle that was low in sawdust bedding, but far from the foot bath area and then mixed with 5 gallons of water.

RESULTS

Benchtop Analysis

In Figure 1, you can see a typical graph of the Biomethane potential experiments carried out at 38 °C with the average of methane production for the three trials displayed. These were performed using the Bioprocess Control AMPTS II unit.



It should be noted that the blank and negative control are almost identical and can hardly be seen on the graph. As displayed in Figure 1, the Telles plastic acts very similarly to the positive control of cellulosic paper with a short induction period. The main difference between the three plastics was the total amount added, two to eight grams. The total vaules for these experiments follow in Table 1 showing very good % of biodegradation of all Telles plastics. The P 5001 plastic was a film that could be used in food wrapping. The P 1008 was thermoformed into plastic utensils and the F 3002 was ground factory beads. It was found that the factory beads need to have their outer shell broken; otherwise the bacteria cannot access the polymer chains effectively to break it down in a timely manner.

Not shown in Figure 1 are Natureworks PLA type plastics. PLA did not show gas production above the blank except for PLA coated paper cups. This gas production however, was from the digestion of the paper since the thin plastic coating could still be found in the container after the 28 day trial. It was later determined that the PLA plastic does not compost below temperatures of 160 °F, or 60 °C which is when the ester bonds of the PLA backbone start to hydrolyze.

Table 1. Benchtop Digestion of Telles Plastics

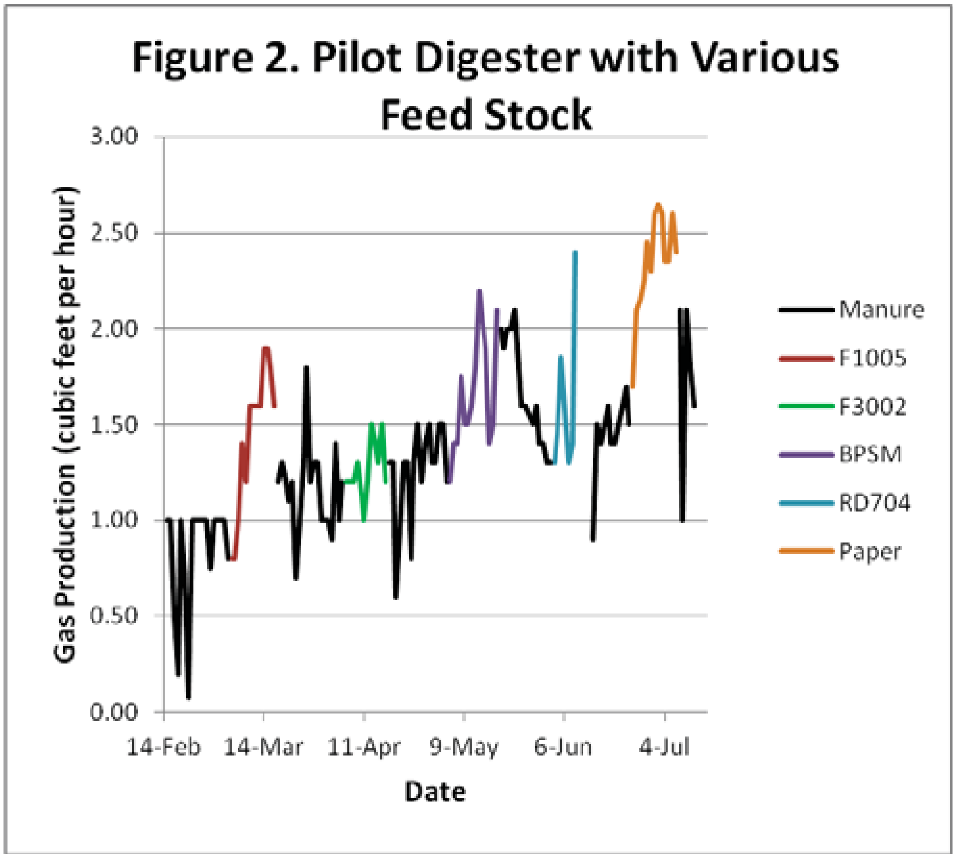
	grams added	Methane Produced (Liters)	% CH_4	% Biodegradation	Methane per gram (L/gram)
Blank	0.000	0.535	64.5		
Positive	8.006	0.572	49.6		
Negative	8.007	3.83	60.6		
P 5001	2.012	1.5	51.8	94.5	0.480
F 3002	2.021	1.48	59.4	91.9	0.468
P 1008	8.022	3.72	57.3	78.5	0.397

PILOT SCALE ANALYSIS

Figure 2, displays the gas production over the time of the experiments at the pilot scale level. Since most of the plastics were digested at the benchtop scale within 14 days, all trials were carried out by adding substrate for 14 days and then followed with 14 days of manure mix only. It was not until looking back at the results that it was determined that this should have been closer to 20 days which is the average retention time of this digester design. The plastics were added with incremental amounts; 2 lbs the first day, 3 lbs the second day, and then 4 lbs every day after until the supply ran out.

The final analysis carried out was adding copier paper that was shredded with a cross cut shredder. For this analysis only 2 lbs of paper was added each day due to the clogging of paper wads. With 10 gallons of manure mix, at about 8 lbs per gallon, this is only an addition of 2.5% by mass, but closer to 40% based on volatile solids. The plastics tested at the pilot scale were the Telles F1005, Telles F3002, BPSM, and Corn Products RD704.

Looking at Figure 2, it becomes quickly apparent that using a gas monitoring device that is only good to 0.2 ft^3 volume/hour lead to very sporadic readings. These readings were only taken once a day and were observed while tank 2 was mixing. This was chosen to try to be consistent from day to day realizing that each tank produced different amounts of gas as well as differences in release when stirring and not stirring.



Many of the plastics in the 200 gallon digester behaved as predicted by the benchtop. The amount of gas production for comparison was determined by taking the last 5 days of gas readings before making changes. This would mean that the baseline used to calculate the increase in gas production for a given plastic was calculated by taking the average of the gas readings for the 5 days before adding the plastic to the manure mix. The plastic gas production was then calculated by averaging the last 5 days of gas production when adding the plastic, for instance, days 9-14. With standard deviations, the gas production for any of the plastics was about the same. What can be said however is that the plastics did not hinder the digestion of the manure.

All of the Telles plastic was digested in the pilot scale digester with no plastic observed in the effluent until the BPSM plastic was added. The BPSM plastic was noticed in the effluent after 9 days of addition. The BPSM plastic factory beads were not ground and were tested in the pilot scale digester in the hopes that the chopper pump or internal pumps of the four tanks would crack the beads.

The Corn Products, #RD704, plastic showed potential according to the benchtop results where it produced 0.20 L of methane per gram of plastic with about 75% of the plastic disappearing. This plastic is not certified to undergo composting as it does contain some non-biodegradable plastic mixed with corn starch. When it was tested in the pilot scale however, the corn starch portion of the plastic turned tank #1 into “gravy”.

That is, the solution became very viscous and plugged the system. Therefore, this test did not last more than 4 days before tank 1 had to be partially drained.

CONCLUSION

The plastics behaved very similarly at the pilot scale when compared to the benchtop in relation to digestion. For instance, all of the Mirel products (F1005 and F3002) broke down with none of the plastic coming out the effluent.

This cracking was only needed for the factory beads as some Mirel thermoformed plastics were tested at the benchtop and the results were the same if not better than the ground factory beads. These beads are how the plastic is typically shipped to the factories where it is processed into a final product, so very few of these should be in a waste stream.

With the limited quantitative ability of the gas monitoring device, it can be determined with only a small amount of confidence if the gas production increased or decreased when substrates were added. In all cases, an increase in gas production was observed. Therefore, the data does support that the benchtop studies are good predictors of digestion at the pilot scale. This study also supports the concept of testing plastics at the pilot scale level before placing large quantities in a full scale digester where any negative consequences could be disastrous.