**IMPACT BIOENERGY**
1001 NW 167th St. Shoreline, WA 98177 USA

# HORSE, AD 25 Narrative for On-Site Foodwaste Processing Demonstration Project Agreement #15-105-Z – December 15, 2016

**HORSE** (**H**igh-solids **O**rganic-waste **R**ecycling **S**ystem with **E**lectrical output), AD 25 microdigester operations at Fremont Brewing Co. continued throughout the fall after Performance Report #2, delivered on September 15, 2016. The following is a courtesy narrative with graphical representations of real performance data. Our official deliverable is the 3rd *Quarterly Report Form* where the reporting period is 91 days long (September 1, 2016 through November 30, 2016).

During the 3rd quarter, given the addition of 1,668 lbs. of brewery, restaurant and donut producer residuals over a feeding period of 91 days, cumulative energy output reached approximately 3,523,020 BTUs (on average approximately 1.03 cf, or 618 BTUs per lb.). *Figure 1*, below, reflects the cumulative mass input and energy output during the period.

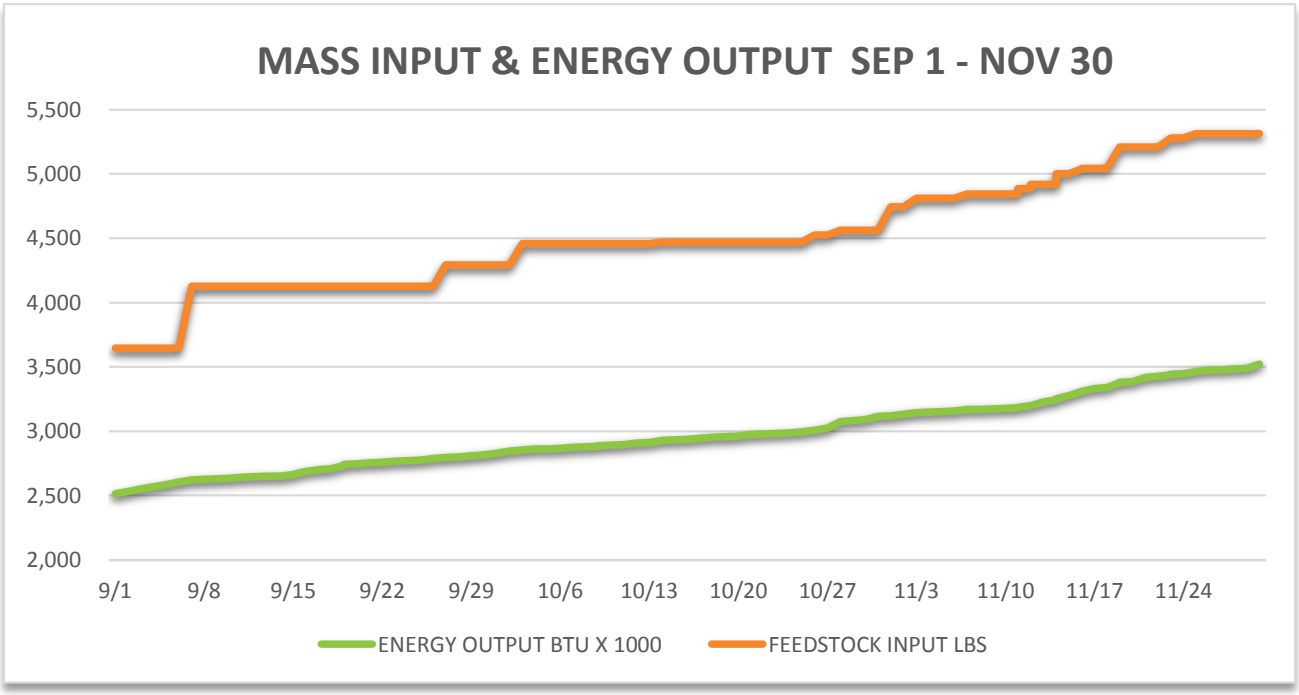


***Figure 1 – Cumulative mass input and energy output.***

On September 7th, at the beginning of the 3rd quarter, we transitioned the feedstock regimen from pure trub to a composite mixture of brewing residuals. This liquid substrate (essentially a single-source organic composition) was comprised of spent yeast, trub and weak wort, and continued to exhibit a pH of approximately 4.5 (similar to the pure trub feedstock). Our concern over the resiliency of the HORSE's microbial community seemed settled after an encouraging display of buffering capacity (i.e. alkalinity) in the prior quarter. For the remainder of September we fed the HORSE only this composite mixture to test resiliency. Over the continued and prolonged period with an acidic diet (starting July 25th), the microbes began to display a lower buffering capacity compared to the prior quarter – pH inside the reactor dropped from 7.5 to 5.5, trending towards a regime where biogas production started to slow down. As shown below, *Figure 2 – Energy output in BTUs per day*, daily energy yield of the HORSE was inhibited beginning in early October.

Since methanogens are known to operate optimally within a pH range of 6 to 8, we began to supplement the composite feedstock with an alkaline blend (50/50 by weight of calcium carbonate and sodium bicarbonate) dissolved

in recycled digestate in order to bring the feedstock pH up to 8.5 and stabilize the digester pH to optimum levels. After approximately 200 lbs. of alkaline blend was supplemented over the month of September, the reactor pH increased to 6. As a result of this experience, in order to keep the reactor functioning properly, standardized operating methods are being designed and implemented (our 4th quarter report will contain more information and feedback from these methods). Monitoring pH is the traditional method of digester control, however a downward shift in pH must be preceded by a loss of the system's alkalinity, therefore pH monitoring is not sufficient since it could be too late to restore healthy biology. Other proactive methods, such as volatile acids/alkalinity tests, may be more effective than pH and gas production monitoring alone.

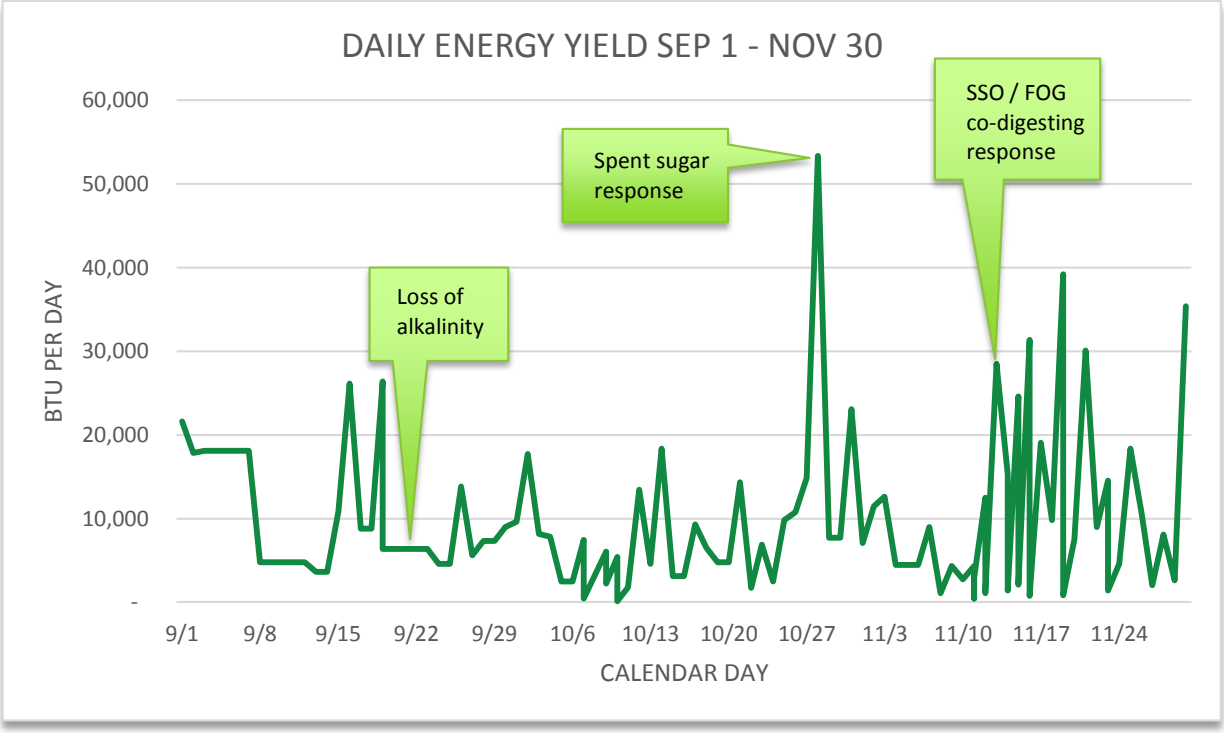


***Figure 2 – Energy output in BTUs per day.***

In October we tested resilience and substrate-biogas response with more spent sugar from a local donut producer, Mighty-O Donuts. As illustrated by the spike in daily energy yield on October 27th, spent sugar from the donut producer has the highest biochemical methane potential (approximately 790 to 970 BTUs per lb.). At the end of October we diverted back to spent yeast brewing residuals, with spent sugar, since it was proven to outperform all other brewery residuals in terms of biogas production.

On November 12th we began co-digesting pre-consumer source separated organics (SSO, primarily surplus French fries and vegetable trimmings) and fats, oil and grease (FOG) from Giddy-up Burgers & Greens, located near the brewery. Operational procedures were performed as-designed with pre-grinding and blending with alkaline supplement to form a pumpable consistency for hydraulic displacement through the system. The dry, paper-like outer onion skins proved to be challenging for the chopper pump since its cellulose is quite robust and blinds the pump suction and pulping process. We also learned that too much FOG impedes digestion (at least while the pH level is sub-optimal). FOG input is therefore being limited to 5% of the overall feedstock split. Effluent pH throughout November consistently measured approximately 5.5 to 6 indicating that methanogens were still not operating at optimal levels. Gas production continues and the combustibility (methane content) are normal.

Once again, all liquid handling was completely enclosed with the exception of the few minutes of mass transfer and input during each feeding. Fruit flies disappeared as the weather cooled and odor control continued to exceed expectations. Approximately 345 gallons of digestate was discharged from the HORSE into intermediate bulk containers, 70 gallons of which was recycled into the system with the alkaline blend while the remaining 275 gallons was used to seed another HORSE. No wastewater was generated.

The HORSE digestate was not pasteurized before being tested for fertility and for public health quality requirements per Title 40 CFR 503.13. In order to analyze the shelf life value of digestate as a biofertilizer, results of ion-exchange resin analysis to determine bioavailable nutrients in stored digestate (decanted on November 17th with analysis performed December 8th) are summarized in *Table 1 – UNIBEST lab results on bioavailable primary macronutrients in stored digestate*, and *Table 2 – Unibest lab results on bioavailable secondary macronutrients and micronutrients in stored digestate*. As expected, on a wet basis the macronutrients were lower than the prior reporting period levels (52 – 166 ppm vs. 80 – 318 ppm) due to volatilization of N during storage (approximately 15 gallons stored in a 30 gallon, vented barrel). On a dry basis the macronutrients are estimated to be 3.3-1.0-2.3 as percentage N-P-K, down from 6.4-1.6-3.4 in the prior reporting period from fresh digestate. Lab results are in ppm, extracted with 50ml 2M HCl.

| Sample Location | # | Depth | Total N | NO3-N | NH4-N | P | K |
|---|---|---|---|---|---|---|---|
| Fremont Brewing | #4 | | 165.80 | 0.00 | 165.80 | 52.04 | 114.70 |
| as received | | | | | | | |
| as reported | | | | | | | |
| | | | | | | | |
| correction to dry basis | | | 3.3% | 0.0% | 3.3% | 1.0% | 2.3% |
| estimated total solids | 0.005 | | | | | | |

***Table 1 – Unibest lab results on bioavailable primary macronutrients in stored digestate.***

| Sample Location | Al | B | Ca | Cu | Fe | Mg | Mn | Na | S | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| Fremont Brewing | 0.31 | 0.05 | 164.67 | 0.04 | 2.30 | 45.05 | 0.14 | 79.19 | 4.79 | 0.07 |
| as received | | | | | | | | | | |
| as reported | | | | | | | | | | |
| | | | | | | | | | | |
| correction to dry basis | 0.0% | 0.0% | 3.3% | 0.0% | 0.0% | 0.9% | 0.0% | 1.6% | 0.1% | 0.0% |
| estimated total solids | | | | | | | | | | |

***Table 2 – Unibest lab results on bioavailable secondary macronutrients and micronutrients in stored digestate.***

pH and conductivity were 6.29 and 14.8 mS/cm respectively. Total metals and pathogens were extremely low in comparison to limits set forth in Title 40 CFR 503.13. Per *Table 3 – AM Test & Fremont Analytical lab results on public health qualities* and *Figure 3 – Percentage metals allowable per Title 40 CFR 503.13*, total metals were between zero and 4.6% of limits. Salmonella tests were Negative per method AOAC 989.13.

According to the revised National Organic Program (NOP) Standard, products of anaerobic digestion processes are considered a generic material that is allowed without restriction and are classified as Crop Fertilizers and Soil Amendments that are acceptable if made from allowed, non-manure feedstock materials[1]. While the product itself is not certified organic, digestate from the HORSE has now been approved by Washington State Department of Agriculture for experimental use on two of our partners' certified organic farms. Since renewable **bio**mass (i.e. food/beverage "waste") is our feedstock and the product is a **bio**active fertilizer with **bio**available primary and secondary micro- and macro-nutrients, we are marketing it as a **biofertilizer**. After our proprietary treatment, biofertilizer is being labelled *Brew Dew: Probiotics for Soil & Plants*. Randomized, replicated commercial growth trials

[1] USDA NOP RULE REFERENCE: 205.105; 205.203(c) REVISION DATE: 10/13/2016

began in September on fall and winter cover crops at Seattle Urban Farm Company's "urban fringe farm" and Seattle Tilth's Red Barn Ranch.

| | | |
|---|---|---|
| Salmonella | MPN/4 g | NEGATIVE |
| conductivity | mS/cm | 14.8 |
| pH | | 6.29 |
| Hg | ug/l | non detect |
| AS | mg/l | 0.00568 |
| Cd | mg/l | 0.000294 |
| Cu | mg/l | 0.15 |
| Pb | mg/l | 0.00155 |
| Mo | mg/l | 0.00923 |
| Ni | mg/l | 0.058 |
| Se | mg/l | 0.00555 |
| Zn | mg/l | 0.649 |

*Table 3 – Am Test & Fremont Analytical lab results on public health qualities.*

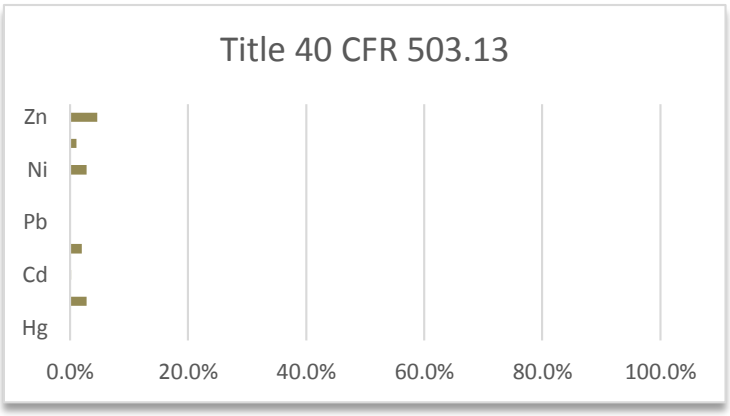


*Figure 3 – Percentage metals allowable per Title 40 CFR 503.13*