

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

HORSE (High-solids Organic-waste Recycling System with Electrical output), AD 25 microdigester operations at Fremont Brewing Co. continued throughout the summer after Performance Report #1, delivered on June 15, 2016. The following is a courtesy narrative with graphical representations of real performance data. Our official deliverable is the 2nd Quarterly Report Form where the reporting period is 92 days long (June 1, 2016 through August 31, 2016).

We continued the feedstock regimen of spent yeast at the beginning of the 2nd quarter. This liquid substrate from the brewery has proven to outperform all other brewery residuals in terms of biogas production (notice the steepness of the green energy output trendline in *Figure 1 – Cumulative mass input and energy output* until about June 15th when we stopped feeding spent yeast).

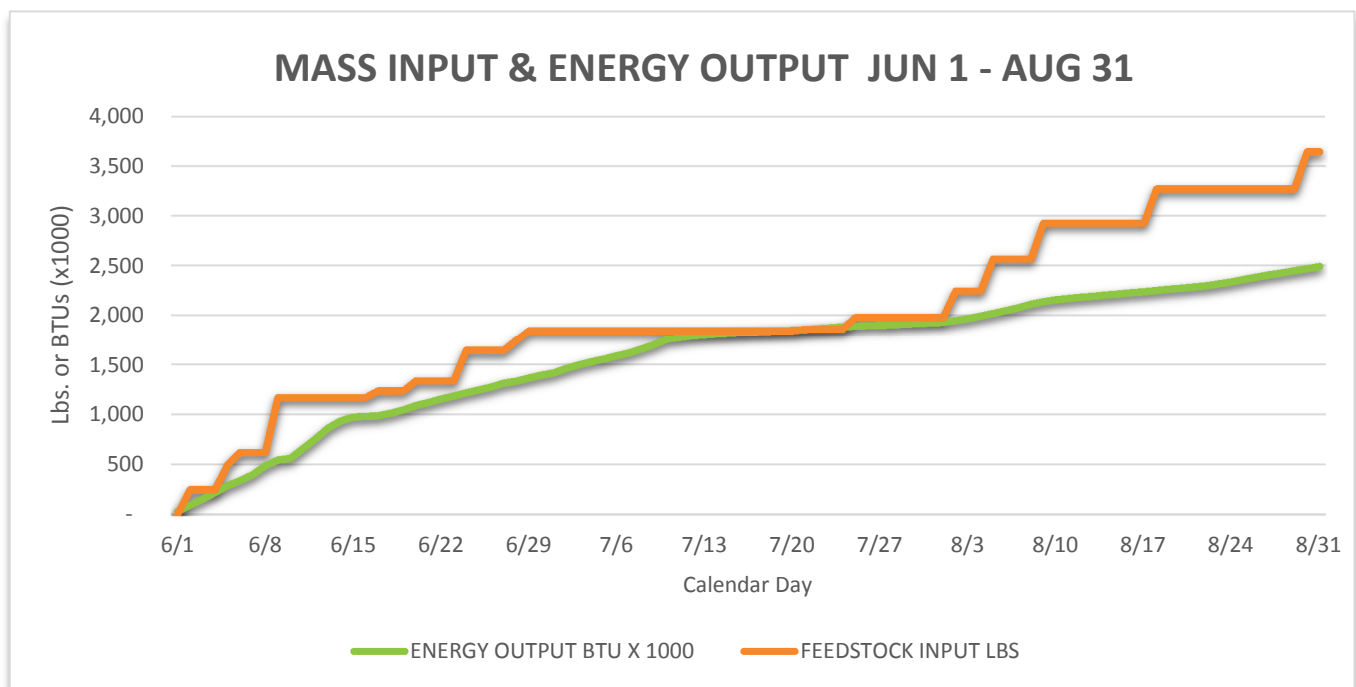


Figure 1 – Cumulative mass input and energy output.

On June 17th we fully transitioned the feedstock to spent grain, which displayed unique properties—it settled above the liquid in the receiving tank and therefore did not get easily pumped automatically into the digester. June 29th was the last day we fed the HORSE spent grain. For most of July, in lieu of water, we recycled liquid digestate in order to keep the spent grain emulsified for pumping. Overall, spent grain proved to be problematic while yielding low amounts of biogas relative to spent yeast (approximately 40 cf per day compared to approximately 170 cf per day).

After priming the microbes with a small amount of spent sugar from a local donut producer to test resilience and substrate-biogas response, and to grow the population of anaerobic microbes, we transitioned the feedstock to spent hops (a.k.a. trub) on July 25th. Alpha acids derived from hops are important in the production of beer as the source of bitterness and as an antibacterial agent that preserved beer for long journeys, such as England to India which earned hoppy beer its name as IPA (India Pale Ale). Trub therefore has a low pH of approximately 4.5, which caused some concern and curiosity over the resiliency of the HORSE’s microbial community. Over the month of August the microbes continued to display a surprisingly healthy buffering capacity at handling the acidic influent. Effluent pH consistently measured at approximately 7.5 (7.68 by SM 4500H+B) while biogas production held steady at approximately 50 cf per day.

Given the addition of 3,646 lbs. of brewery residuals over a feeding period of 92 days, energy output reached approximately 2,492,000 BTUs (on average approximately 1.14 cf, or 684 BTUs, per lb.). Below, *Figure 2 – Energy output in BTUs per day*, shows daily energy yield of the HORSE during the period.

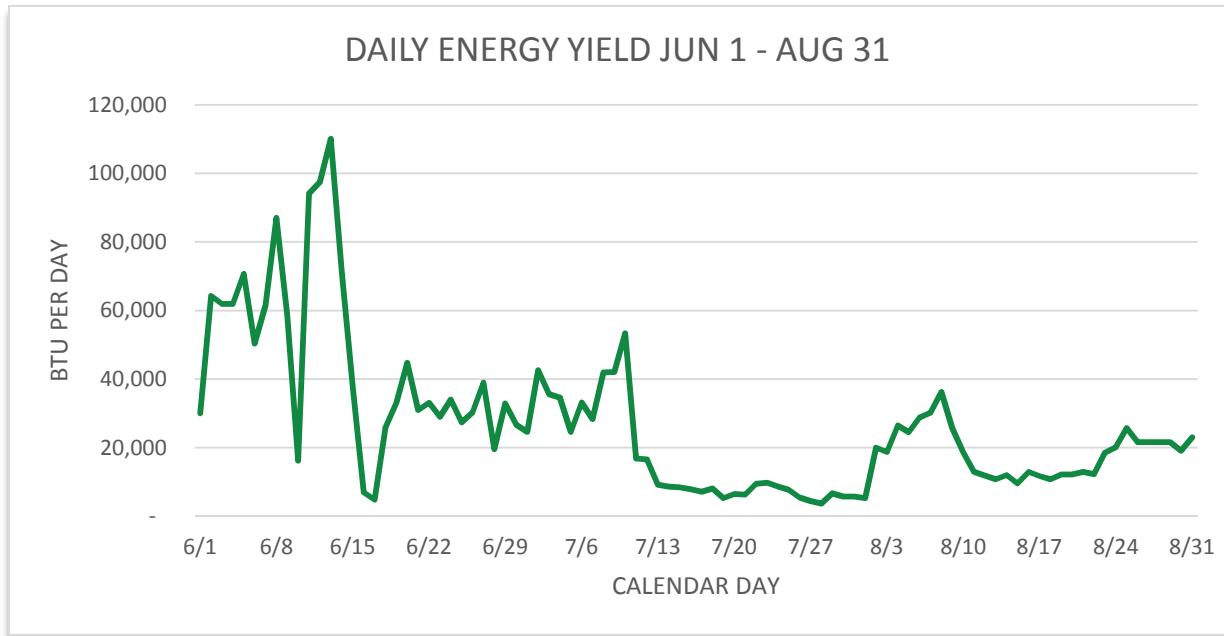


Figure 2 – Energy output in BTUs per day.

Operational procedures were performed as-designed. All liquid handling was completely enclosed with the exception of the few minutes of mass transfer and input during each feeding. In the heat of the summer fruit flies found their way to the receiving tank, but odor control once again exceeded expectations. Digestate was discharged from the HORSE into intermediate bulk containers. 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. Results of ion-exchange resin analysis to determine bioavailable nutrients are summarized in *Table 1 – UNIBEST lab results on bioavailable primary macronutrients*, and *Table 2 – Unibest lab results on bioavailable secondary macronutrients and micronutrients*. As expected, on a wet basis the macronutrients were higher than the prior reporting period levels (80–318 ppm vs. 28–265 ppm) due to very low total solids content during startup (diluted feedstock). On a dry basis the macronutrients are estimated to be 6.4-1.6-3.4 as percentage N-P-K, up from 5.3-0.6-3.3 in the first reporting period. Lab results are in ppm, extracted with 50ml 2M HCl.

Sample Location	#	Depth	Total N	NO3-N	NH4-N	P	K
Fremont Brewing	#2		317.85	0.00	317.85	80.14	168.93
as received							
as reported							
correction to dry basis			6.4%	0.0%	6.4%	1.6%	3.4%
estimated total solids	0.005						
Brew Dew (treated Aug 15)	#3		379.00	0.00	379.00	56.62	196.67
correction to dry basis			7.6%	0.0%	7.6%	1.1%	3.9%
estimated total solids	0.005						

Table 1 – Unibest lab results on bioavailable primary macronutrients.

Sample Location	Al	B	Ca	Cu	Fe	Mg	Mn	Na	S	Zn
Fremont Brewing	0.48	0.03	32.14	0.02	2.47	28.40	0.22	17.18	7.33	0.04
as received										
as reported										
correction to dry basis	0.0%	0.0%	0.6%	0.0%	0.0%	0.6%	0.0%	0.3%	0.1%	0.0%
estimated total solids	0.005									
Brew Dew (treated Aug 15)	0.27	0.04	13.41	0.03	0.67	4.14	0.29	25.40	6.10	0.04
correction to dry basis	0.0%	0.0%	0.3%	0.0%	0.0%	0.1%	0.0%	0.5%	0.1%	0.0%
estimated total solids	0.005									

Table 2 – Unibest lab results on bioavailable secondary macronutrients and micronutrients.

pH and conductivity were 7.68 and 15.2 mS/cm respectively. Total metals and pathogens were very 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 47% of limits. With respect to Title 40 CFR 503.32 Pathogens, per EPA method 1682, Salmonella was < 2 Most Probable Number per four grams of total solids which meets Class A pathogen requirements of < 3 MPN/4g for unrestricted sale and use.

The HORSE generated approximately 454 gallons of liquid digestate during the reporting period. According to the revised National Organic Program (NOP) Standard, products of anaerobic digestion processes are allowed without restriction and are classified as Crop Fertilizers and Soil Amendments that are acceptable if made from allowed, non-manure feedstock materials¹. Digestate from this HORSE has been approved by Washington State Department of Agriculture for experimental use on our partner’s certified organic farm. Commercial growth trials began September 10th on fall and winter cover crops.

After our proprietary treatment, digestate is [being marketed to beta testers as biofertilizer, Brew Dew: Probiotics for Soil & Plants](#) with macronutrients estimated to be 7.6-1.1-3.9 as percentage N-P-K on a dry basis (43% higher N, 98% higher P and 18% higher K than our May 31st baseline lab results, and 19% higher N, 29% lower P and 18% higher K than the raw digestate reported in Table 1, see #3 vs. #2). Early non-commercial growth trials showed positive anecdotal results. Plants treated with *Brew Dew* show more observable vigor and biomass, with seemingly better immunity to disease than untreated plants.

Salmonella	MPN/4 g	< 2
conductivity	mS/cm	15.2
pH		7.7
Hg	ug/l	non detect
AS	mg/l	0.0019
Cd	mg/l	0.00154
Cu	mg/l	0.134
Pb	mg/l	0.00994
Mo	mg/l	0.00865
Ni	mg/l	0.263
Se	mg/l	0.00479
Zn	mg/l	6.62

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

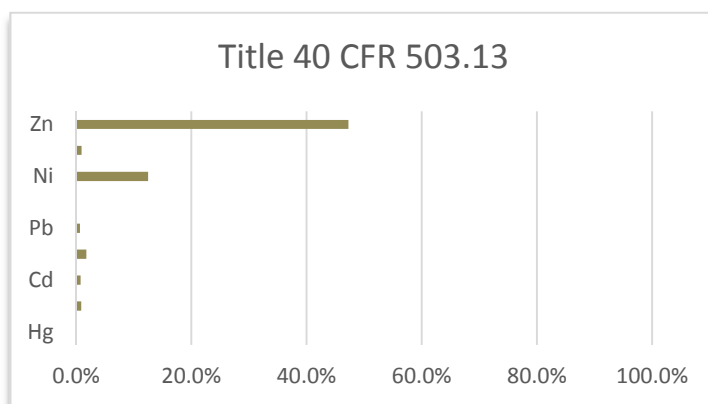


Figure 3 – Percentage metals allowable per Title 40 CFR 503.13

¹ USDA NOP RULE REFERENCE: 205.105; 205.203(c) REVISION DATE:08/05/2016