Positive energy balance at Käppala wastewater treatment plant – just the beginning

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Introduction

Käppala WWTP in Stockholm, Sweden, has since 2013 shown a positive energy balance. The energy content in the produced biogas and heat delivered to district heating exceeds the energy demand for the WWTP operation. The key part in reaching this milestone has been a system approach in the ongoing optimization of the WWTP´s sub-processes. Improvements of the anaerobic sludge digestion have been the main contributor. Today, Käppala´s organic material removal is characterized by a high degree of separation in the primary clarifier from which the sludge is fed to a serial mesophilic two reactor configuration. The energy efficient digester heating solution is almost exclusively based on heat exchangers and heat pumps. The digester heating demand accounts for about 5% of the WWTPs total electricity use.

This poster describes the latest approach of the ongoing systems oriented optimization. The aim was to find the optimum digestion temperature in terms of heating energy demand versus biogas production.

Materials and Methods

Six 2L lab scale semi-continuously fed reactors (AMPTSII Bioprocess Control, Lund, Sweden) were allocated two and two into water baths of 34, 37 and 40 °C. Reactors were fed once daily Monday through Friday, including double feeding on Fridays for Saturdays´ feed while Sundays´ feed was divided over the other weekdays. The substrate source was identical as for the full-scale digester (thickened primary sludge) while the Hydraulic Retention Time (HRT) and Organic Loading Rate (OLR) were kept as closely as possible to the 37 °C full-scale digester to increase transferability of the results.

Results

Out of a total experiment time of circa 18 HRT including start-up (ca 2.8 HRT), temperature change and acclimatization (ca 4.4 HRT), the final 7.8 HRT were used to evaluate methane yield from digesting at the different temperatures.

Figure 1 shows the accumulated methane production after each feeding up until a) 5, and b) (up to) 78 hours, presented per weekday and digestion temperature. As expected, there is a trend with increased methane production with increasing digestion temperature in the first hours after feeding as can be seen in subplot 1a. However, this trend is gradually evened out over time and is non significant (Dunn´s test, p>0.05) after (up to) 78 hours after feeding (subplot 1b).

Table 1 shows a comparison of process parameters between full-scale and lab-scale during the evaluation period.

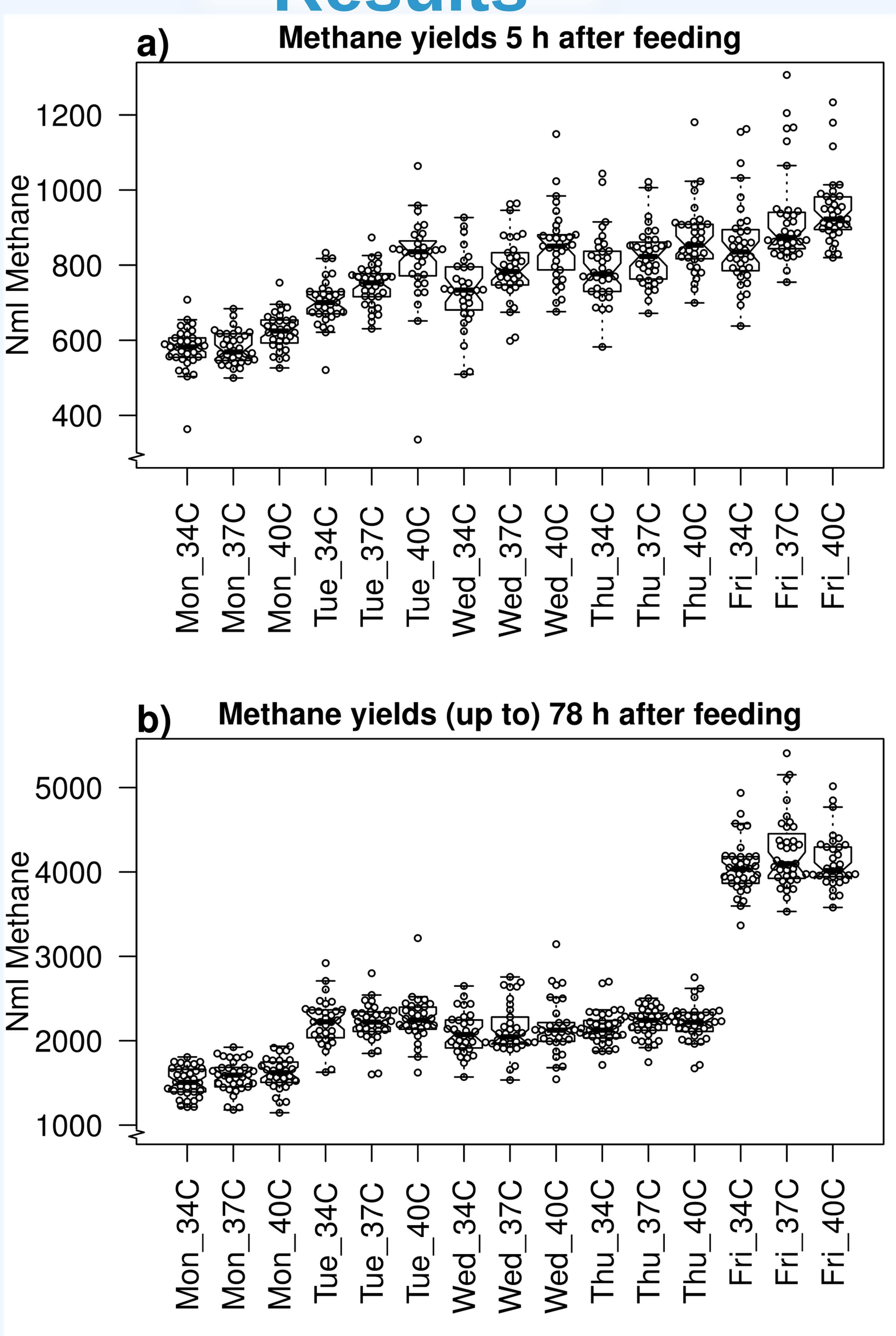

Figure 1. Accumulated methane after each feeding.
Box: 25-75 percentiles. Whiskers: 1.5 interquartile length. Thick line: Median. Notches: 95% conf. int. of the median.

Parameter		Full-scale	34 °C	37 °C	40 °C
HRT [days]	Mean	15	16	16	16
OLR [kg VS·m^{-3}·d^{-1}]	Mean	3.3	3.0	3.0	3.0
TS, Primary sludge [%]	Mean	5.5	5.5	5.5	5.5
	SD	0.73	0.59	0.59	0.59
	N	23	24	24	24
VS, Primary sludge [% of TS]	Mean	86.0	86.8	86.8	86.8
	SD	2.28	1.83	1.83	1.83
	N	23	24	24	24
pH [-]	Mean	7.2	7.1	7.2	7.2
	SD	0.06	0.06	0.07	0.07
	N	27	134	136	136
SMY [$NL_{CH4} \cdot g_{VSfed}^{-1}$]	Mean	0.35	0.34	0.35	0.35
	SD	0.03	0.02	0.02	0.02
	N	26	23	23	23
Biogas methane content [v/v% CH_4]	Mean	65	66	67	67
	SD	1	4	3	3
	N	4328	86	86	86
VFA [mg·L^{-1} as acetic acid]	Mean	94	102	115	122
	SD	15.6	77.5	52.6	30.1
	N	11	38	38	38
Alkalinity pH 5.4 [mg·L^{-1} as $CaCO_3$]	Mean	3632	3294	3550	3647
	SD	148	314	332	398
	N	12	44	44	42
Alkalinity pH 4.5 [mg·L^{-1} as $CaCO_3$]	Mean	3725	3382	3646	3761
	SD	129	300	303	368
	N	12	44	44	42
TS, Digester [%]	Mean	2.6	2.8	2.7	2.7
	SD	0.1	0.2	0.2	0.2
	N	22	38	37	38
VS, Digester [% of TS]	Mean	69.7	72.6	72.2	72.3
	SD	0.9	1.7	1.5	2.3
	N	22	38	38	38

Table 1. Process parameters from lab-, and full-scale.

Conclusions

Even though initially higher methane production rates at higher digestion temperatures is evident in the lab-scale, lower temperature reactors catch up in accumulated production over time at the tested OLR and HRT. Comparisons of process parameters point towards good transferability of lab-scale results to full-scale. Lowering the digestion temperature from 37 to 34 °C without decreased biogas production is calculated to save Käppala about 400 MWh yearly in reduced electricity demand, corresponding to about 10% of the electricity demand for digester heating.