Anaerobic Co-Digestion of Food Waste and Sewage Sludge: Bench-Scale Study

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30 October 2013

Project Team

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Purpose

- To evaluate the anaerobic co-digestion of sewage sludge (SS), from Deer Island Treatment Plant (DITP), and food waste (FW) for varying mixtures with regards to:
  - Biogas production
  - Solids reduction
  - System stability
  - Nutrient impact on side-streams

Dates to Note

- Semi-Continuous Anaerobic Co-Digestion Study
  - Start date: February 22nd, 2013 (Digesters seeded)
  - Feeding and wasting: started February 26th, 2013 (project day 4)
  - End date: July 26th, 2013 (>5 SRTs)
  - Study Period: 150 days
  - April 18th: R2 (100% FW set) failed and new R2 re-seeded as control (100% feed sludge)
  - May 6th (project day 74) SRT changed from 28 to 22 days

Semi-Continuous Co-Digestion Study Set-up

Digester ID	Feed Composition		Food Waste			Feed Sludge (DITP)		
	(w/w)		TS (%)	Feed (L)	Mass (%)	TS (%)	Feed (L)	Mass (%)
R1	100%	Feed Sludge	15.0%	0.0	0%	5.2%	0.200	100%
R2	100%	FW	15.0%	0.200	100%	5.2%	0.0	0%
R3	10%	FW	15.0%	0.010	10%	5.2%	0.240	90%
R4	20%	FW	15.0%	0.020	20%	5.2%	0.230	80%
R5	20%	FW	15.0%	0.020	20%	5.2%	0.230	80%
R6	50%	FW	15.0%	0.065	50%	5.2%	0.185	50%

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R6	50%	FW	15.0%	0.065	50%	5.2%	0.185	50%

R2: later changed to the second control (100% feed sludge)

Operation of Anaerobic Digesters

- Mesophilic digestion: 37°C
- Working volume of reactors: 4L
- Daily Feeding: 250 mL of fresh feed (sewage sludge and/or food waste)
- Daily Wasting: 250 mL of digested biomass
- SRT: No feeding on weekends (SRT normalized)
  - Day 0-73: 28 days
  - Day 74-154: 22 days

Setup and Operation of Semi-continuous Digestion

Digesters were stirred using constructed rotating chambers at 100 rpm

Semi-Continuous Study Sampling and Analysis

Sampling Day	Parameter	Methods / Instruments	Standard Methods
M-F	pH	pH Meter (Orion GS9156)	4500-H+B
TH	CH_4 and CO_2	GC-TCD	-
T, TH	Ammonium ion	Cation chromatography	4500-NH_3
T, TH	Dissolved PO_4-P	Anion chromatography	4500-PO_4-P
T, TH	Dissolved Mg	Cation chromatography	
T	sTN	Hach reagent sets	-
T	sTP	Hach reagent sets	-
T, TH	COD	Standard Methods	5220D
M,W,F	TS and VS	Standard Methods	2540
T, TH	Alkalinity	Standard Methods	2320
T, TH	Volatile Acid Alkalinity	Standard Methods	
T	CST	Standard Methods	2710G

Digester Feed, Seed and Food Waste

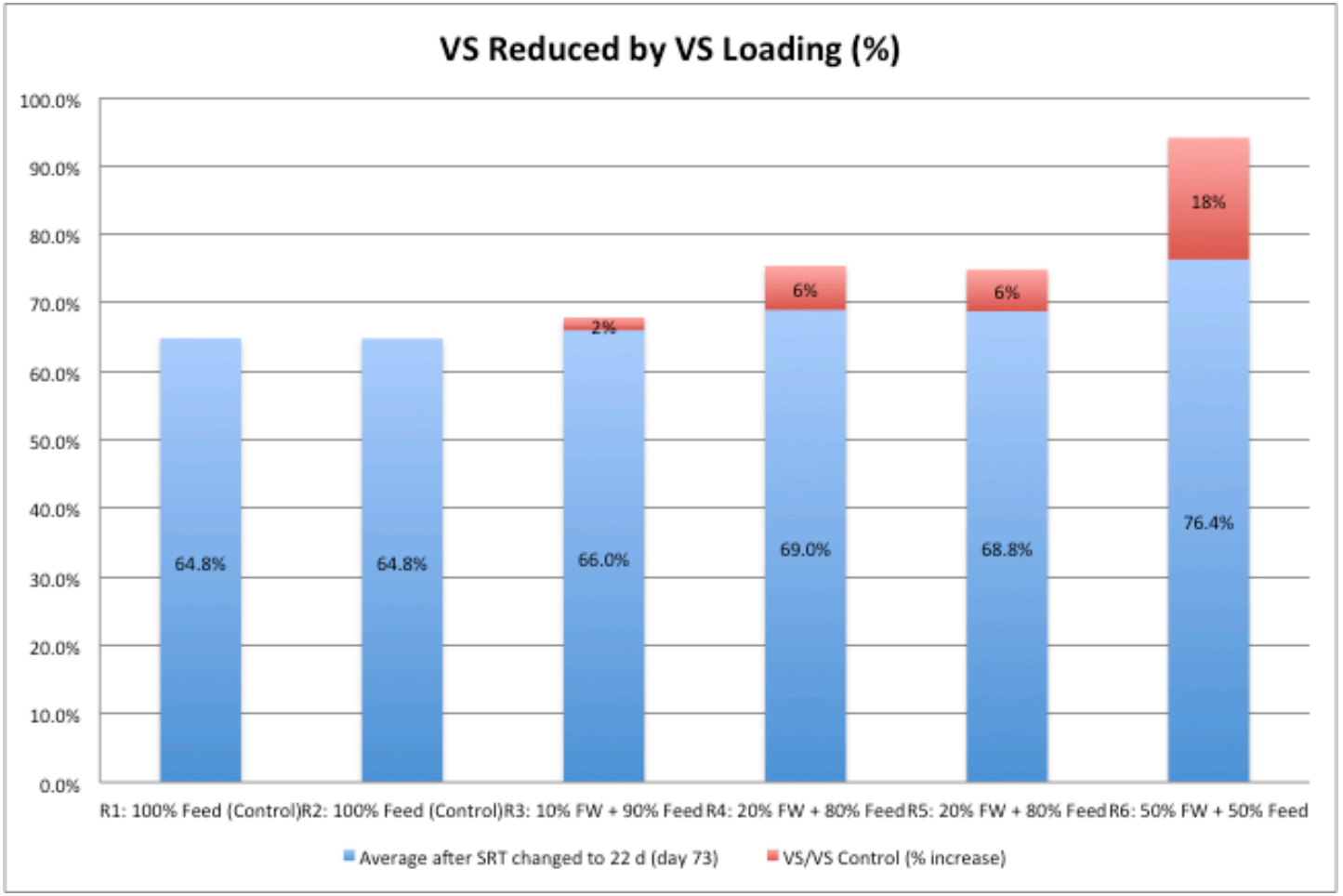
	TS (%)	VS (%)	VS/TS (%)
Feed Sludge (DITP)	5.1%	4.2%	83.1%
Seed Sludge	2.5%	1.7%	66.9%
Food Waste	15.4%	13.6%	88.4%

Solids Loading Rate

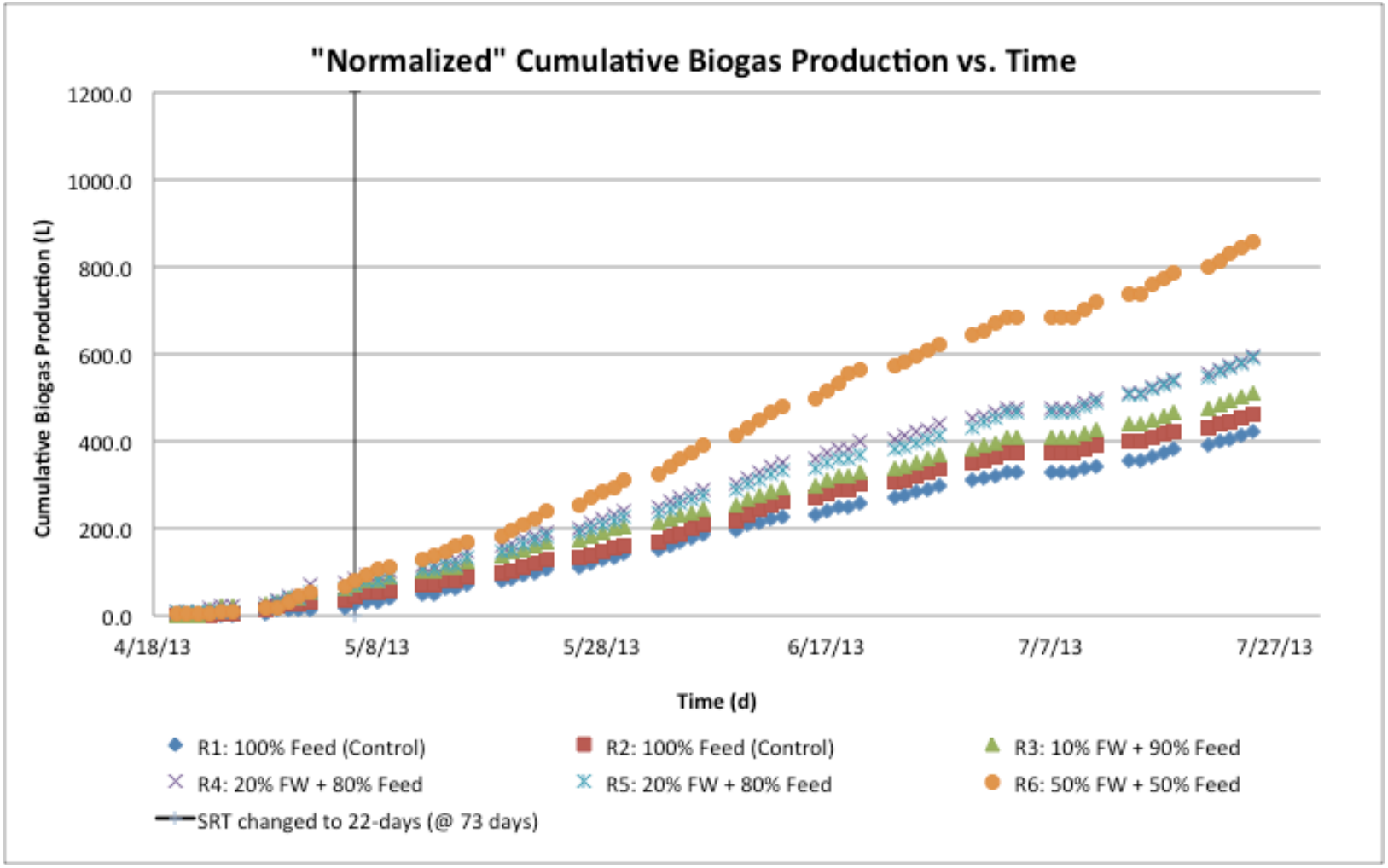
Average Data: May 9 to July 26 (~4 SRTs)

	FW/(FW+SS) (%)	Average TS (%)	Average VS (%)	VS/TS (%)	VS loading (kg VS/m^3-d)	VS loading (lb VS/ft^3-d)	VS/VS Control (% increase)
R1	0	5.0	4.1	83.0	2.58	0.16	
R2	0	5.0	4.1	83.0	2.58	0.16	
R3	10	5.4	4.5	83.5	2.83	0.18	9.6
R4	20	5.9	4.9	83.6	3.08	0.19	19.2
R5	20	5.9	4.9	83.6	3.08	0.19	19.2
R6	50	7.9	6.7	84.6	4.19	0.26	62.2

Volatile Solids Reduction Efficiency



Biogas Cumulative Production

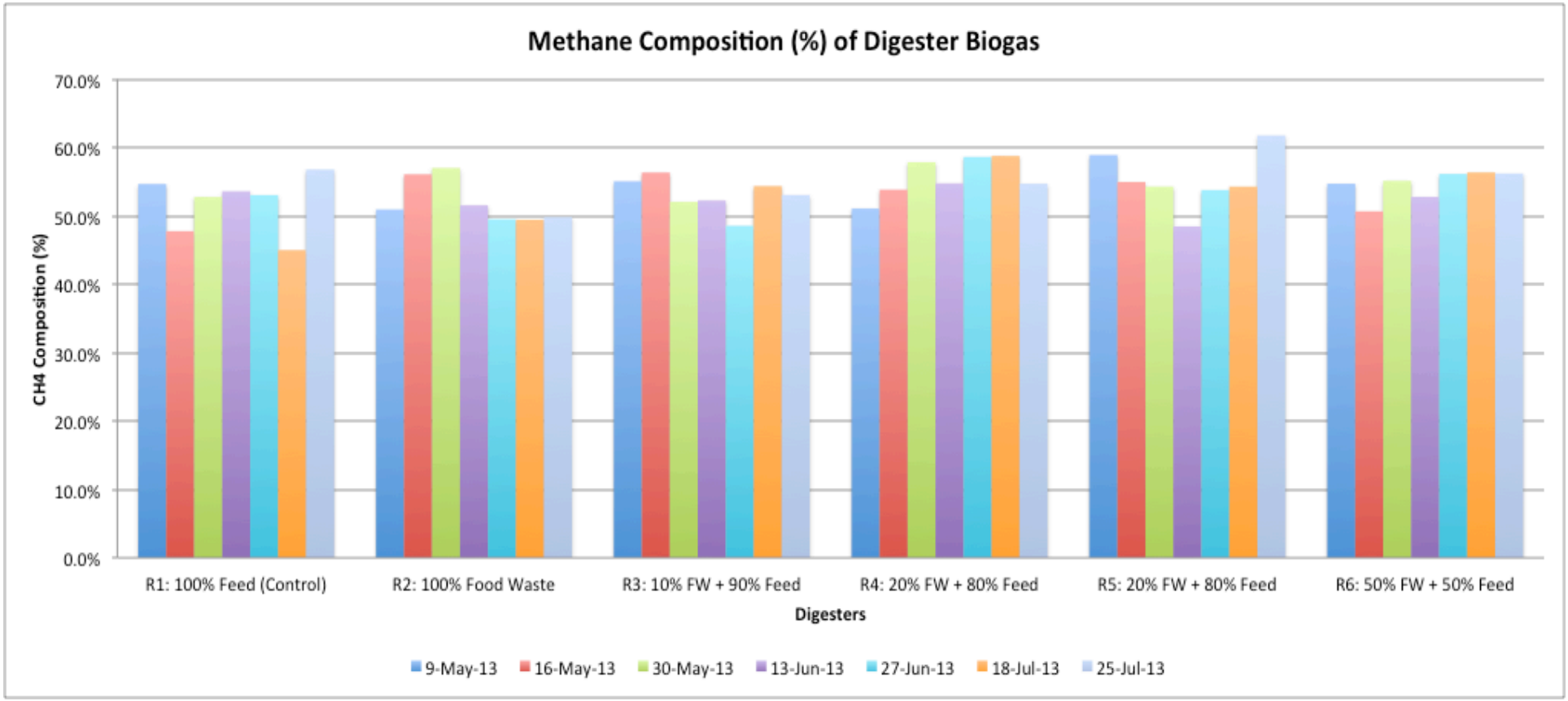


Biogas Generation Rates and Yields

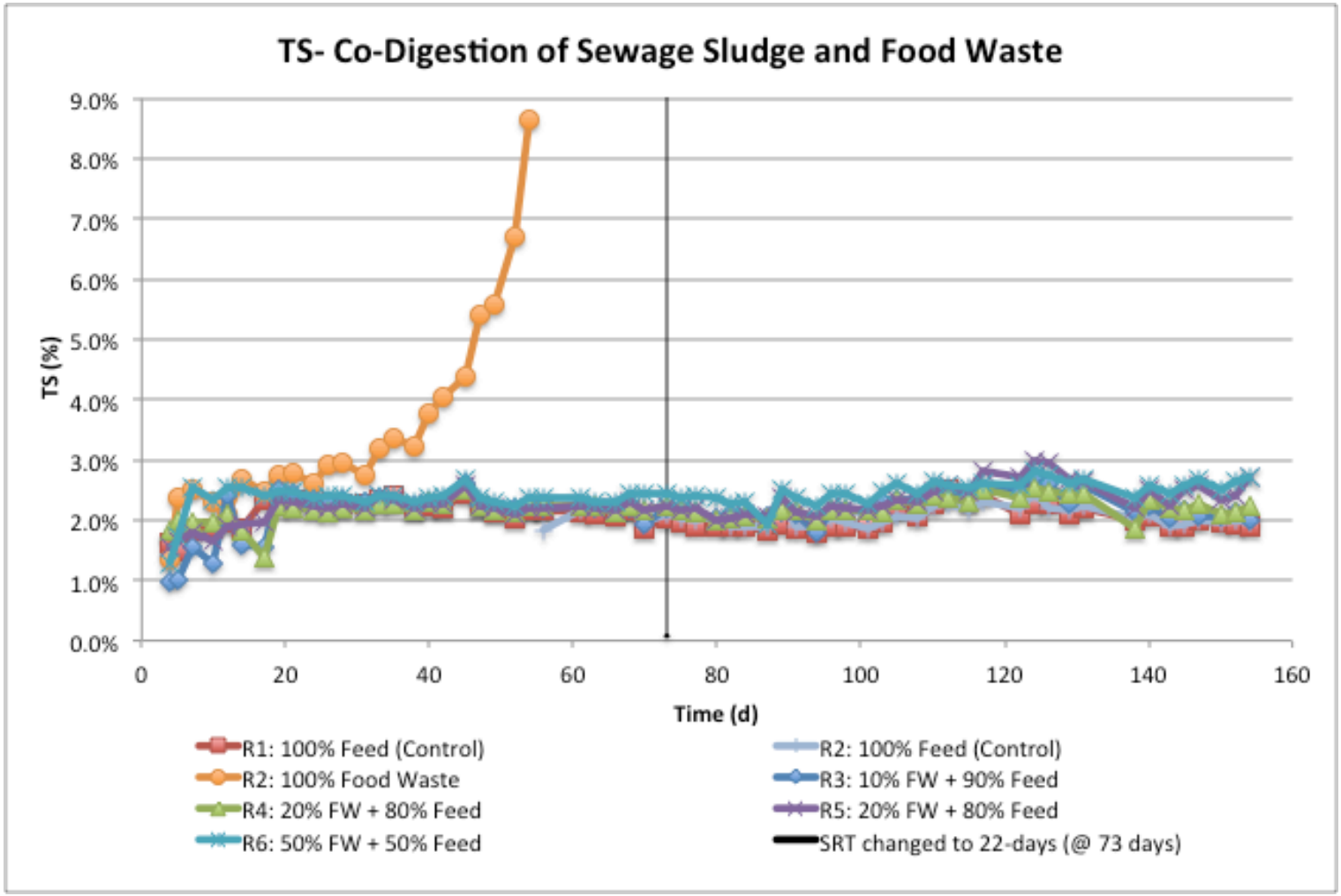
Cumulative Biogas Production for 22-d SRT (since May 6)			
	FW/(FW+SS) (%)	(L/d)	(ft^3/d)
R1	0	3.7	0.13
R2	0	4.2	0.15
R3	10	4.8	0.17
R4	20	5.6	0.20
R5	20	5.4	0.19
R6	50	7.8	0.28

Average Biogas Yields for 22-d SRT(since May 6)					
	FW/(FW+SS) (%)	(L/g VS Fed)	(ft^3/lb VS Fed)	(L/g VS Reduced)	(ft^3/lb VS Reduced)
R1	0	0.51	8.1	0.62	9.97
R2	0	0.60	9.6	0.73	11.73
R3	10	0.65	10.5	0.80	12.75
R4	20	0.70	11.2	0.85	13.60
R5	20	0.65	10.5	0.80	12.80
R6	50	0.66	10.6	0.81	12.94
	Std. Dev.	0.07	1.1	0.08	1.3

Biogas Composition



Total Solids in the Digesters



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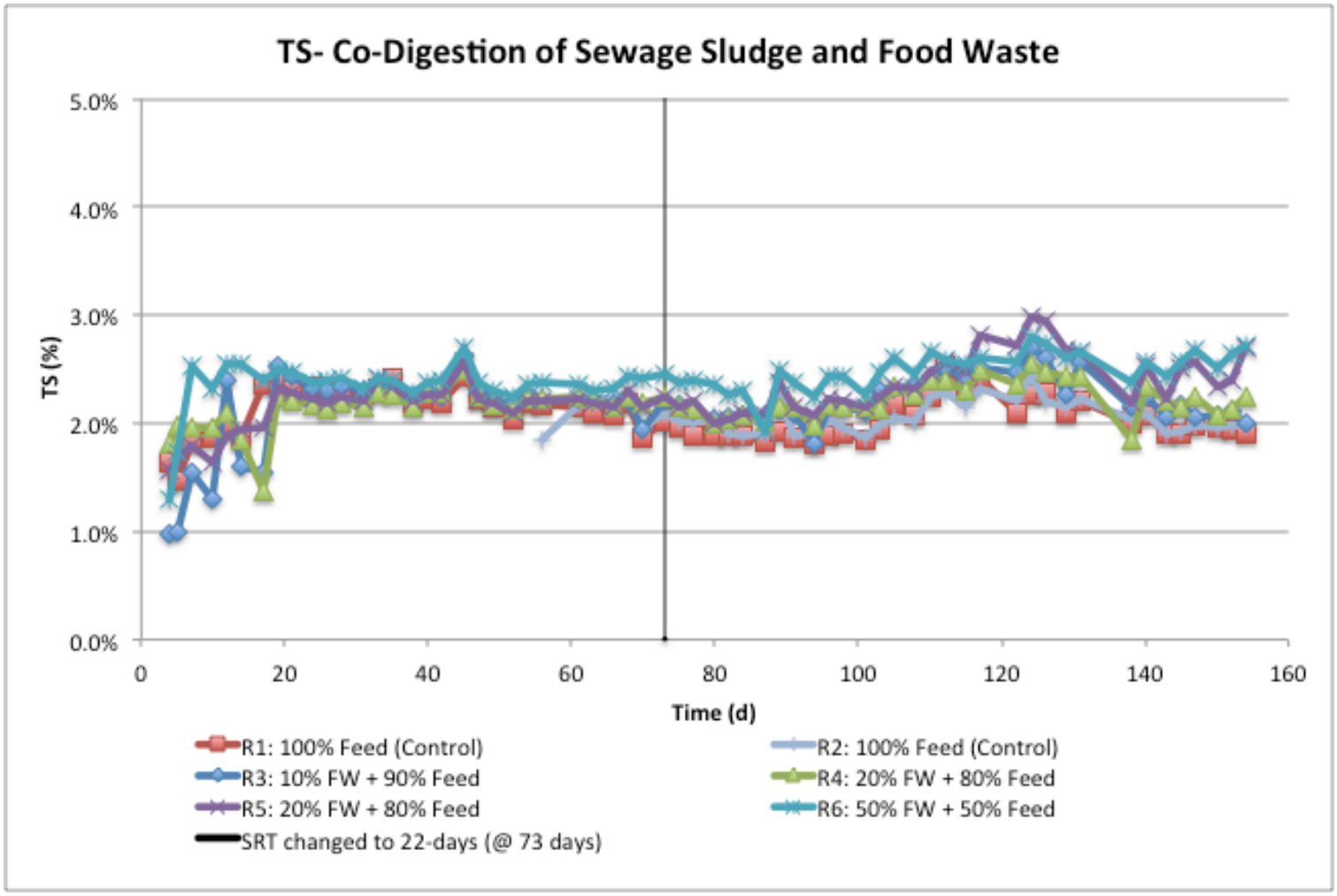
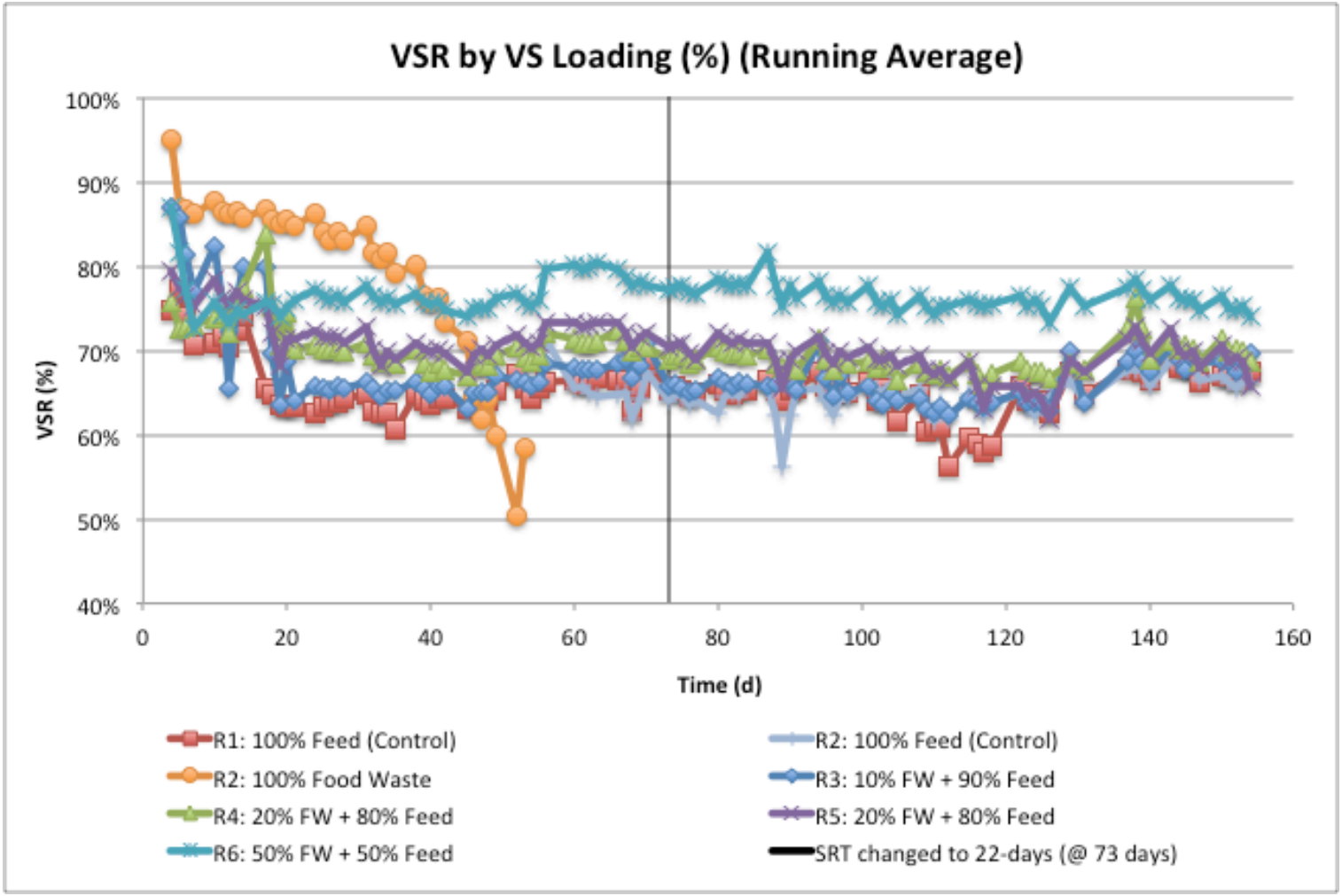
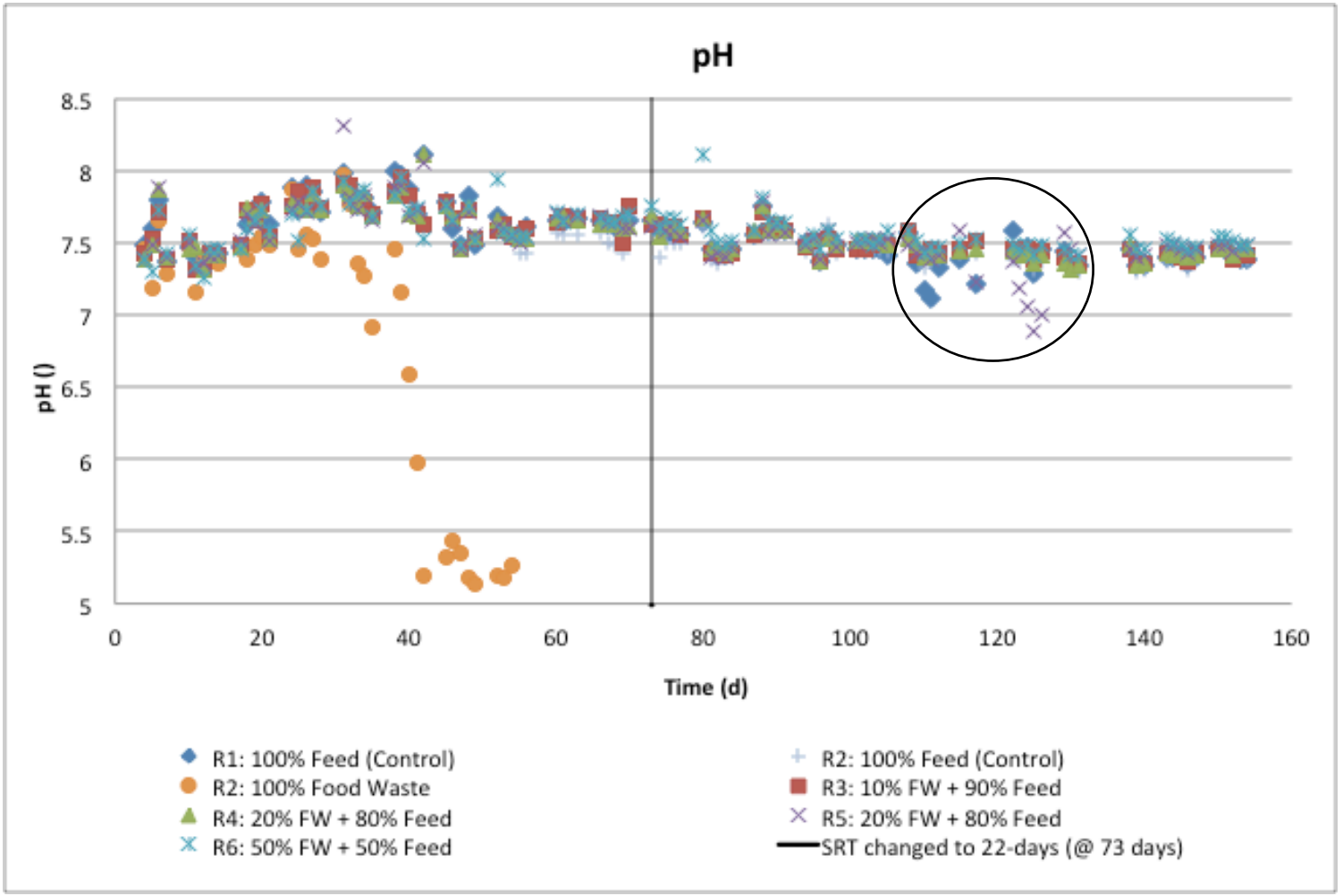


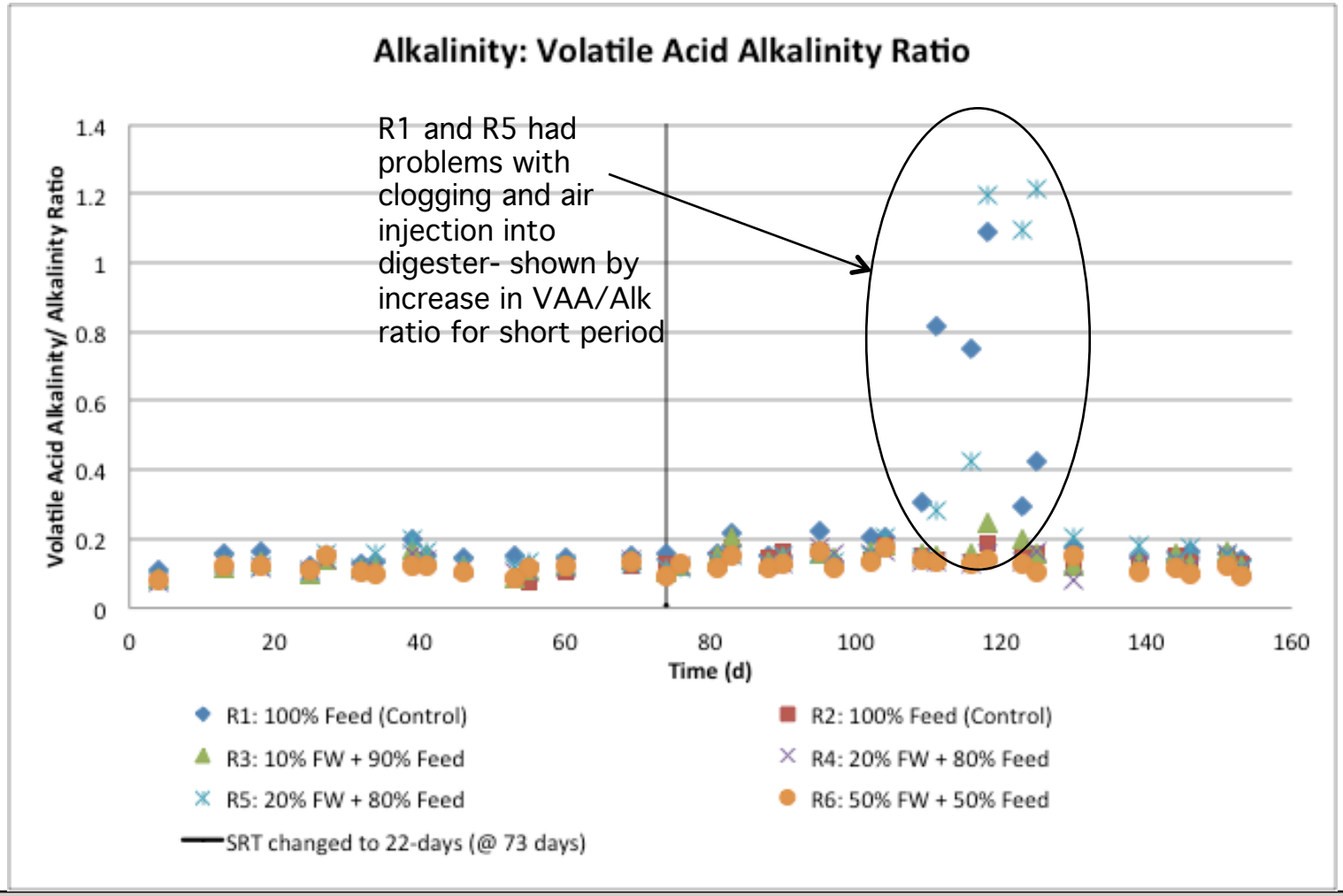
Volatile Solids Reduction by VS Loading



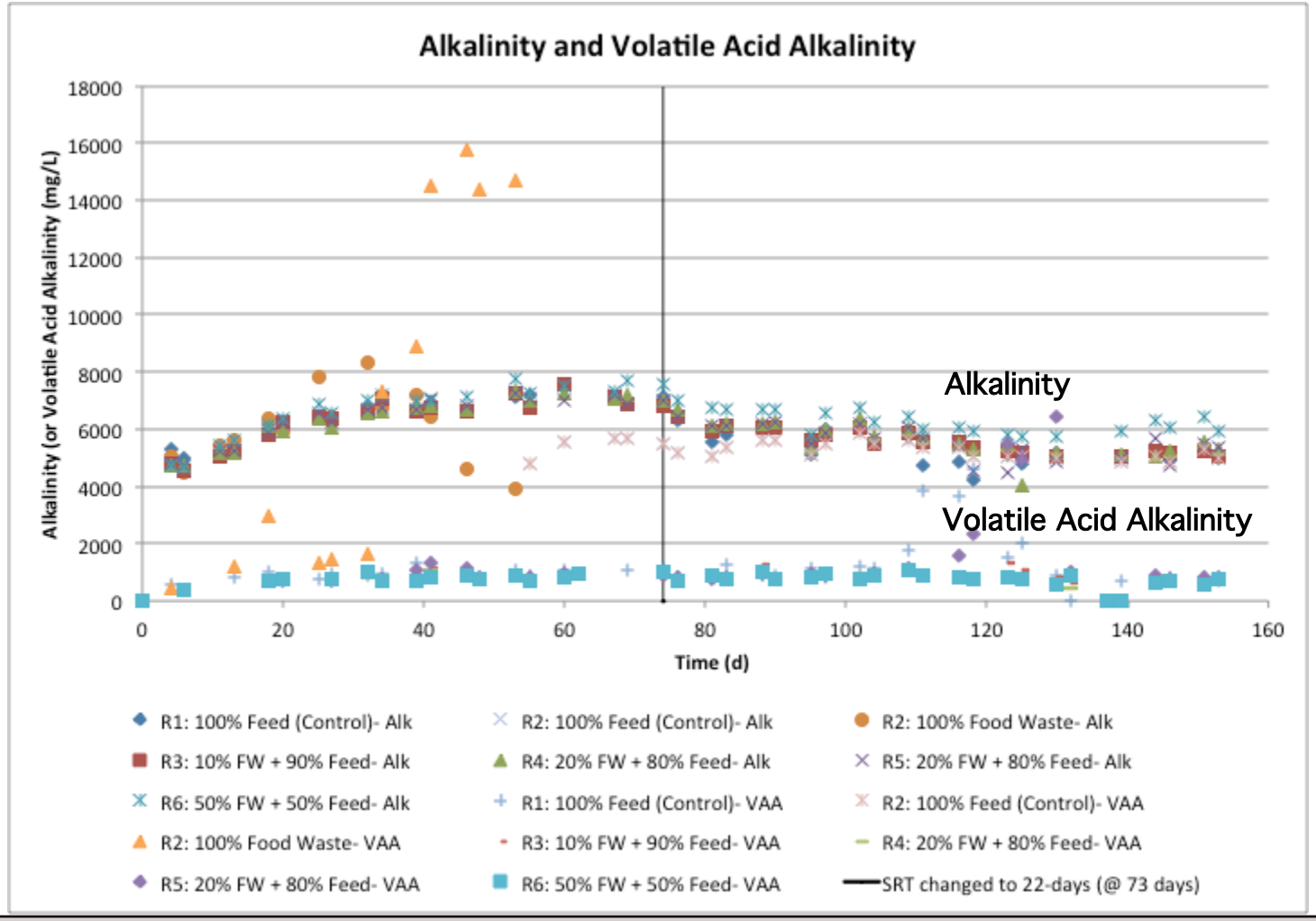
pH


pH
8.5
8
7.5
7
6.5
6
5.5
5
pH ()
0
20
40
60
80
100
120
140
160
Time (d)
R1: 100% Feed (Control)
R2: 100% Food Waste
R4: 20% FW + 80% Feed
R6: 50% FW + 50% Feed
R2: 100% Feed (Control)
R3: 10% FW + 90% Feed
R5: 20% FW + 80% Feed
SRT changed to 22-days (@ 73 days)

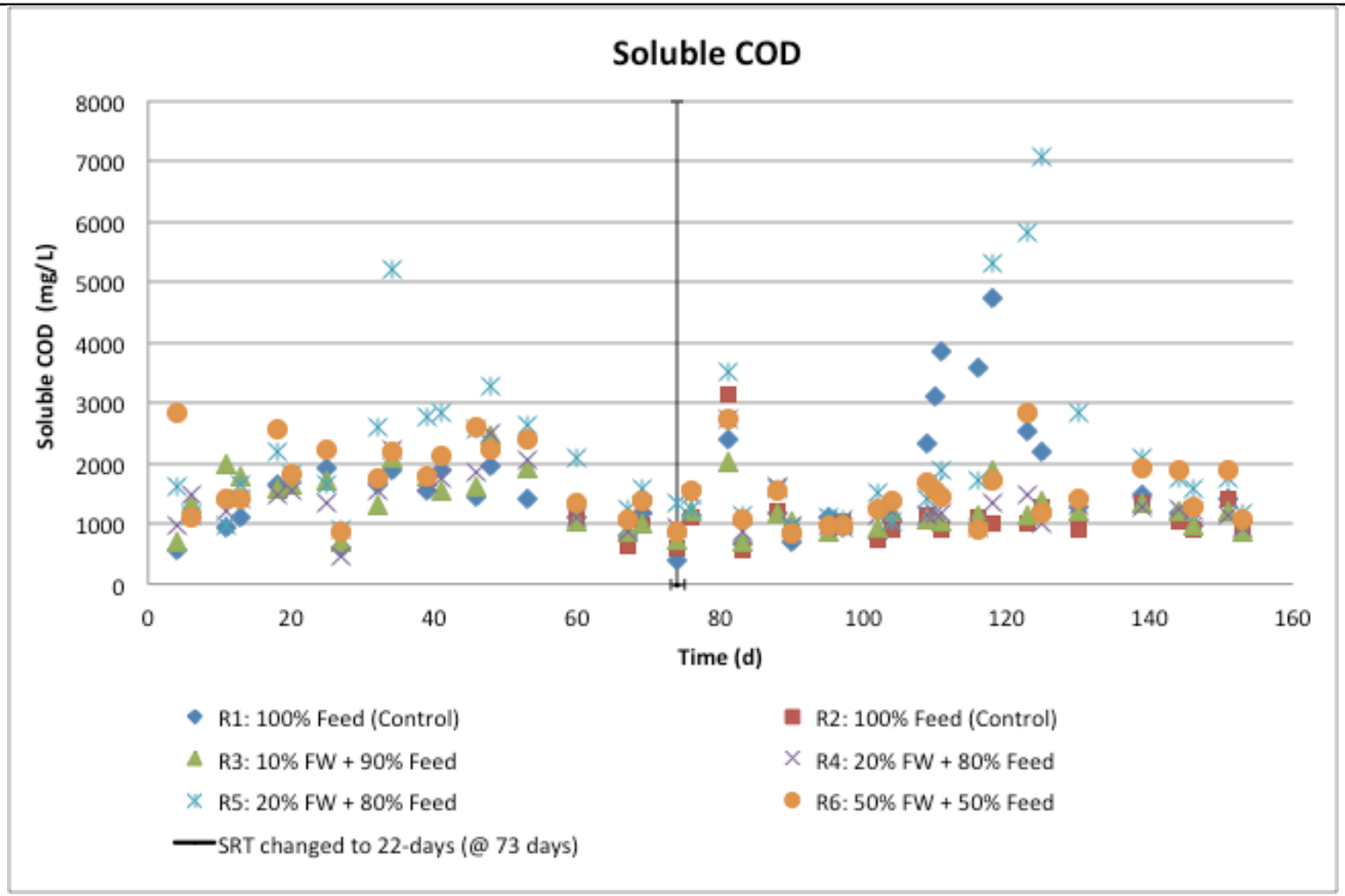
Alkalinity: Volatile Acid Alkalinity Ratio



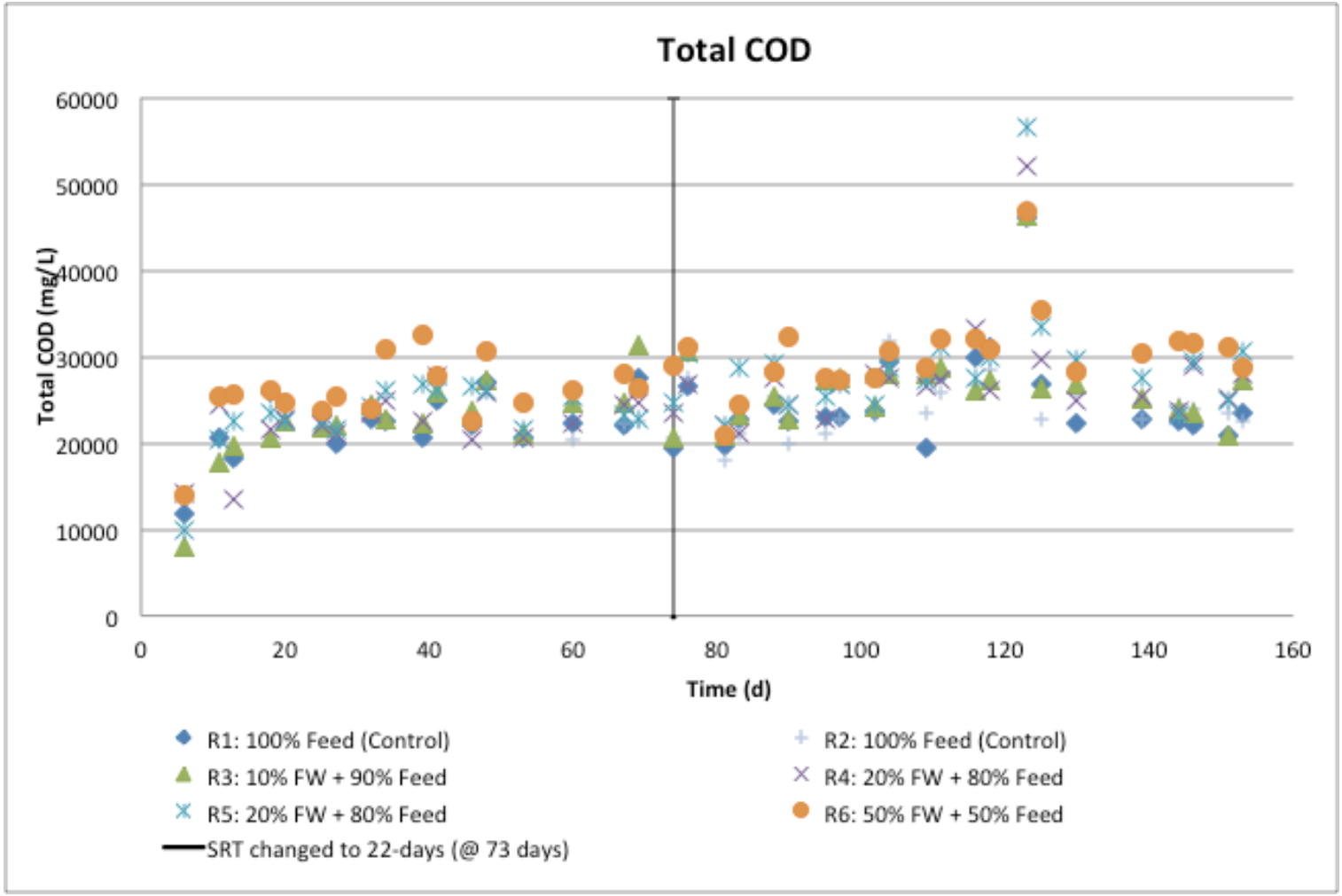
Alkalinity and Volatile Acid Alkalinity



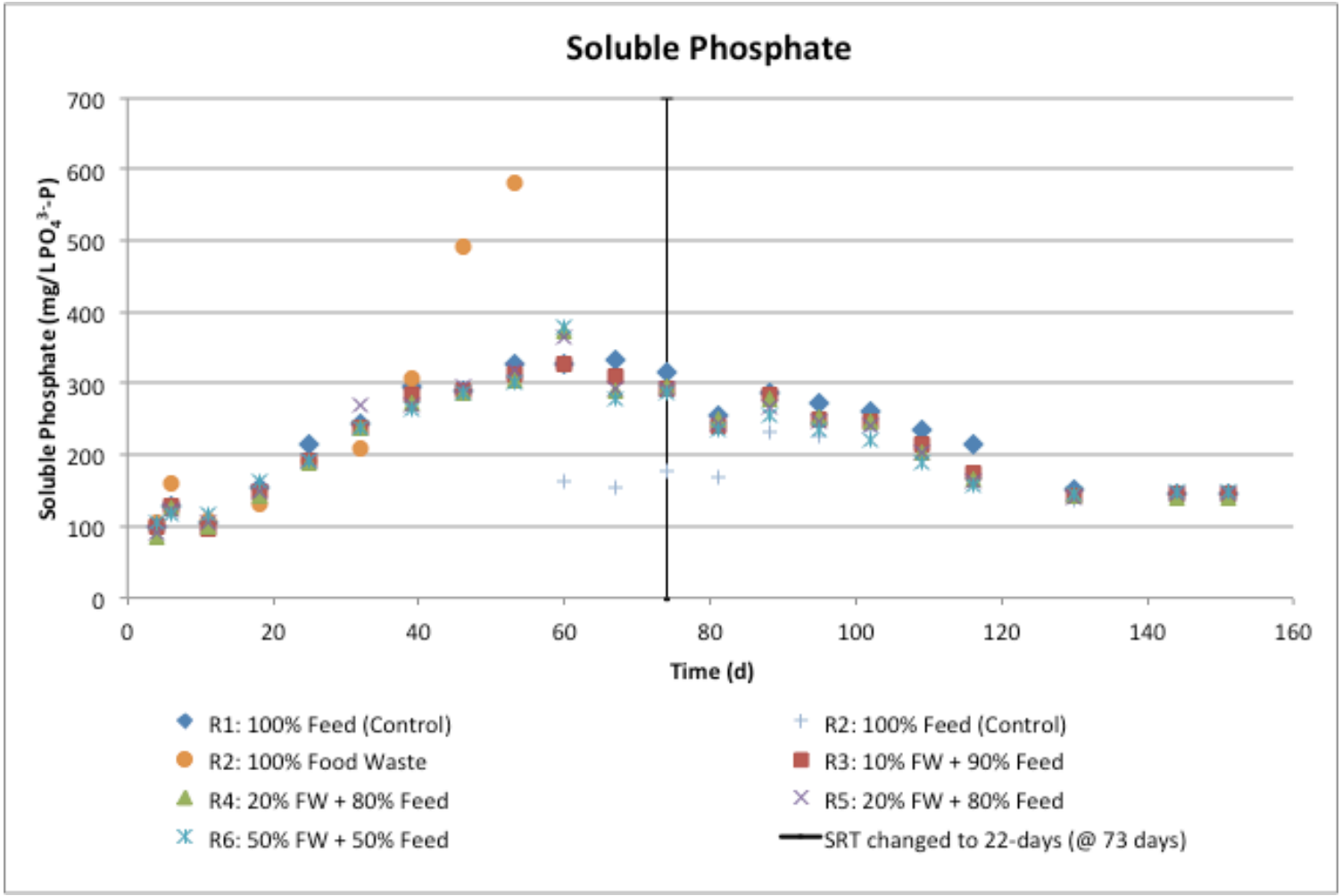
Soluble COD


Soluble COD
Soluble COD (mg/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
20
40
60
80
100
120
140
160
Time (d)
R1: 100% Feed (Control)
R2: 100% Feed (Control)
R3: 10% FW + 90% Feed
R4: 20% FW + 80% Feed
R5: 20% FW + 80% Feed
R6: 50% FW + 50% Feed
SRT changed to 22-days (@ 73 days)

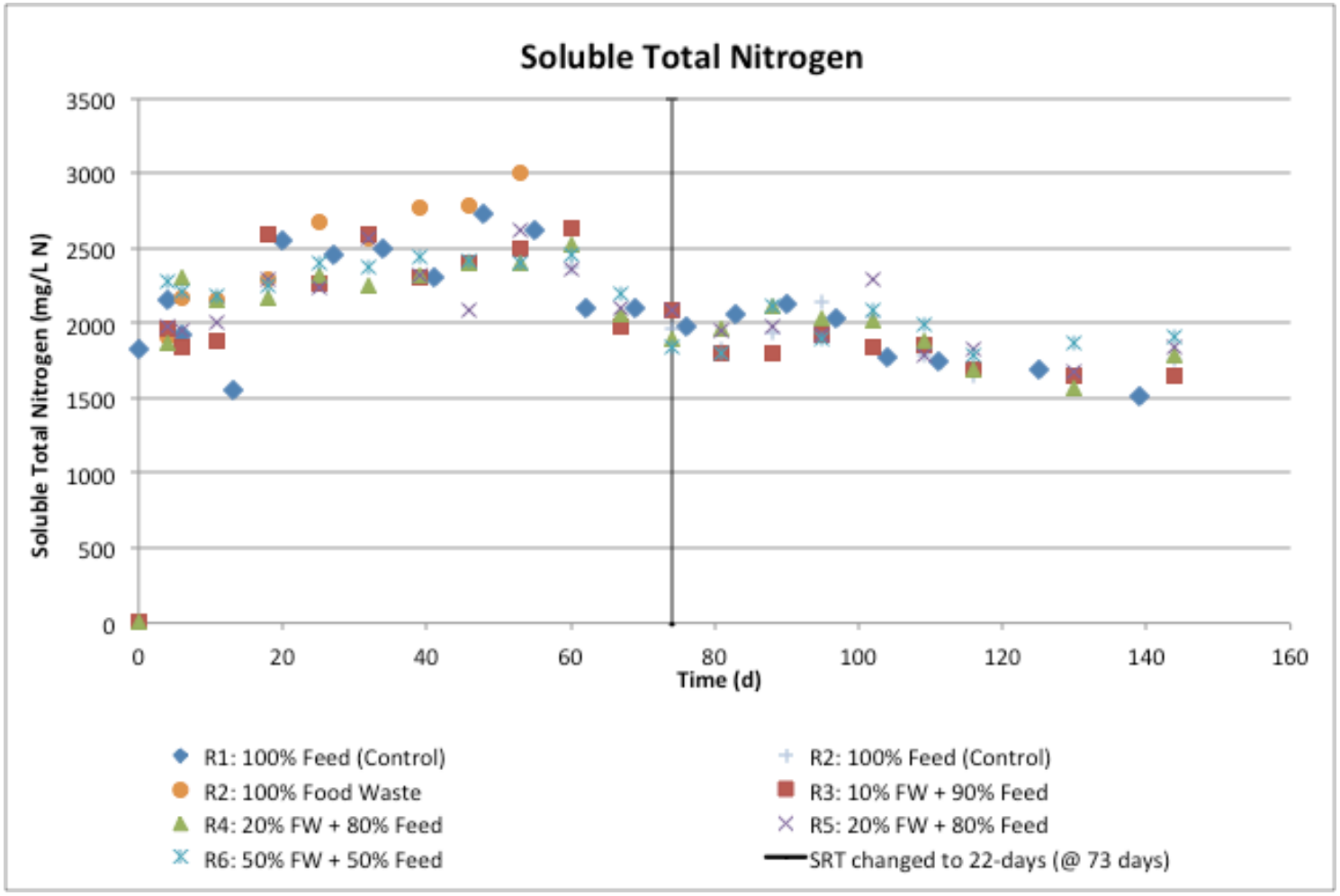
Total COD


Total COD
60000
50000
40000
30000
20000
10000
0
Total COD (mg/L)
0
20
40
60
80
100
120
140
160
Time (d)
R1: 100% Feed (Control)
R2: 100% Feed (Control)
R3: 10% FW + 90% Feed
R4: 20% FW + 80% Feed
R5: 20% FW + 80% Feed
R6: 50% FW + 50% Feed
SRT changed to 22-days (@ 73 days)

Nutrients: Soluble Phosphate



Nutrients: Soluble Nitrogen



Comparison to EPA EBMUDS Report

Parameter	Units	Food Waste Co-Digestion 22-day MCRT Meso	Co-Digestion Control 22-day MCRT Meso	EBMUDS Food Waste Digestion 15-day MCRT Meso	EBMUDS Municipal Wastewater Solids Digestion 15-day MCRT Meso
VS (as percent of TS), Feed	%	83.8-84.8	83.7	86.3	77
VS Loading, Feed	lb/ft^3-day	0.19-0.27	0.16	0.28	0.20
COD Loading, Feed	lb/ft^3-day	0.52-2.01	0.28	0.55	0.06-0.3
VSD	%	66.0-76.4	64.8	73.8	38-57
Methane CH_4 Content	%	53.1-55.7	52	64	63

Summary

- Increased biogas production
- No Negative effects on system stability
- Increased biogas yield
- Similar P and N concentrations

Acknowledgements

Project co-funded and supported by,

- MWRA
- Massachusetts Clean Energy Center (MaCEC)

Questions?