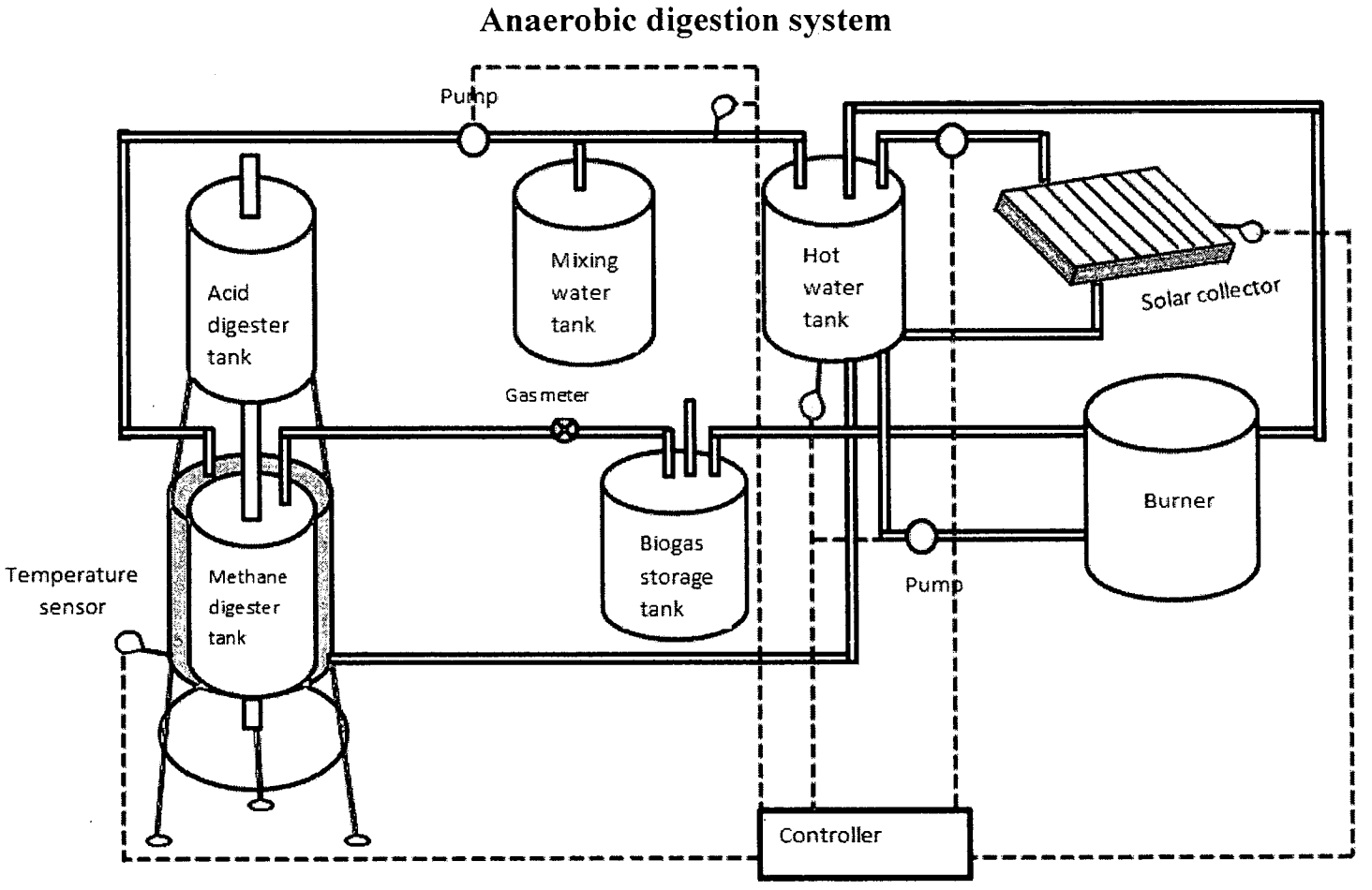
Appendix A Anaerobic digestion system



Appendix B Volume of tank and heat losses rate of hot water

Volume of tank and heat losses rate of hot water

Volume of tank

Size of tank (L)	Diameter (m)	Length (m)
150	0.59	0.77
200	0.59	1.14
300	0.59	1.38
400	0.66	1.39
550	0.82	1.39
750	0.91	1.41
900	1.02	1.42
1,100	1.11	1.44
1,600	1.31	1.45
2,000	1.39	1.78
2,500	1.39	1.91
3,000	1.39	2.25
4,000	1.53	2.73
5,000	1.53	3.19
6,000	1.53	3.67

Heat losses rate of hot water

v1	v2	v2-v1	Flow rate 15 L./h		Flow rate 20 L./h		Flow rate 25 L./h		Flow rate 30 L./h		Flow rate 35 L./h	
			time (h.)	Q (kW)	time (h.)	Q (kW)	time (h.)	Q (kW)	time (h.)	Q (kW)	time (h.)	Q (kW)
150	400	250	16.7	1050	12.5	1050	10	1050	8.3	1050	7.1	1050
150	550	400	26.7	1680	20	1680	16	1680	13.3	1680	11.4	1680
150	750	600	40	2520	30	2520	24	2520	20	2520	17.1	2520
200	400	200	13.3	840	10	840	8	840	6.7	840	5.7	840
200	550	350	23.3	1470	17.5	1470	14	1470	11.7	1470	10	1470
200	750	550	36.7	2310	27.5	2310	22	2310	18.3	2310	15.7	2310
250	400	150	10	630	7.5	630	6	630	5	630	4.3	630
250	550	300	20	1260	15	1260	12	1260	10	1260	8.6	1260
250	750	500	33.3	2100	25	2100	20	2100	16.7	2100	14.3	2100
400	550	150	10	630	7.5	630	6	630	5	630	4.3	630
400	750	350	23.3	1470	17.5	1470	14	1470	11.7	1470	10	1470
400	900	500	33.3	2100	25	2100	20	2100	16.7	2100	14.3	2100
550	750	200	13.3	840	10	840	8	840	6.7	840	5.7	840
550	900	350	23.3	1470	17.5	1470	14	1470	11.7	1470	10	1470
550	1100	550	36.7	2310	27.5	2310	22	2310	18.3	2310	15.7	2310
750	900	150	10	630	7.5	630	6	630	5	630	4.3	630
750	1100	350	23.3	1470	17.5	1470	14	1470	11.7	1470	10	1470
750	1600	850	56.7	3570	42.5	3570	34	3570	28.3	3570	24.3	3570
900	1100	200	13.3	840	10	840	8	840	6.7	840	5.7	840
900	1600	700	46.7	2940	35	2940	28	2940	23.3	2940	20	2940
900	2000	1100	73.3	4620	55	4620	44	4620	36.7	4620	31.4	4620

Heat losses rate of hot water (Cont.)

v1	v2	v2-v1	Flow rate 15 L./h		Flow rate 20 L./h		Flow rate 25 L./h		Flow rate 30 L./h		Flow rate 35 L./h	
			time (h.)	Q (kW)	time (h.)	Q (kW)	time (h.)	Q (kW)	time (h.)	Q (kW)	time (h.)	Q (kW)
1100	1600	500	33.3	2100	25	2100	20	2100	16.7	2100	14.3	2100
1100	2000	900	60	3780	45	3780	36	3780	30	3780	25.7	3780
1100	2500	1400	93.3	5880	70	5880	56	5880	46.7	5880	40	5880
1600	2000	400	26.7	1680	20	1680	16	1680	13.3	1680	11.4	1680
1600	2500	900	60	3780	45	3780	36	3780	30	3780	25.7	3780
1600	3000	1400	93.3	5880	70	5880	56	5880	46.7	5880	40	5880
2000	4000	2000	133.3	8400	100	8400	80	8400	66.7	8400	57.1	8400
2000	5000	3000	200	12600	150	12600	120	12600	100	12600	85.7	12600
2000	6000	4000	266.7	16800	200	16800	160	16800	133.3	16800	114.3	16800
2500	4000	1500	100	6300	75	6300	60	6300	50	6300	42.9	6300
2500	5000	2500	166.7	10500	125	10500	100	10500	83.3	10500	71.4	10500
2500	6000	3500	233.3	14700	175	14700	140	14700	116.7	14700	100	14700
3000	4000	1000	66.7	4200	50	4200	40	4200	33.3	4200	28.6	4200
3000	5000	2000	133.3	8400	100	8400	80	8400	66.7	8400	57.1	8400
3000	6000	3000	200	12600	150	12600	120	12600	100	12600	85.7	12600

Appendix C Size of flat plate

Size of flat plate

Flow rate of water (L/h)	Hot water (L/day)	Size of flate plate (m^2)
5	120	1.66
10	240	3.32
15	360	4.98
20	480	6.65
25	600	8.31
30	720	10
35	840	11.63
40	960	13.29
45	1080	14.95

Appendix D Biogas production and composition

Biogas production and composition

Temperature 35 °C

**( ) Data from GC

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 1				
1	2.02	47.90	40.32	11.78
2	1.89	48.92	40.08	11.00
3	2.20	49.54	39.36	11.10
4	2.21	50.65	39.75	9.60
5	2.20	51.73	39.27	9.00
6	2.30	53.95	38.14	7.91
7	2.21	55.47	37.03	7.50
8	2.37	56.73 (55.09)	36.25 (36.99)	7.02 (7.92)
9	2.31	56.49	36.13	7.38
10	2.43	57.85	34.15	8.00
11	2.48	58.79	33.51	7.70
12	2.52	58.64	33.36	8.00
13	2.57	60.91	31.09	8.00
14	2.41	58.73	31.57	9.70
15	2.52	58.83 (58.01)	30.12 (30.89)	11.05 (11.1)

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 2				
1	1.59	47.30	40.30	12.40
2	1.74	49.40	40.00	10.60
3	2.25	50.82	37.43	11.75
4	2.22	52.73	38.02	9.25
5	2.30	52.09	39.71	8.20
6	2.06	53.72	37.11	9.17
7	2.58	54.95 (54.13)	36.56 (37.25)	8.49 (8.62)
8	2.43	56.39	34.42	9.19
9	2.38	57.64	34.10	8.26
10	2.35	57.08	34.35	8.57
11	2.20	58.69	33.57	7.74
12	2.43	59.12	32.34	8.54
13	2.62	59.93	31.65	8.42
14	2.41	60.62 (59.94)	32.12 (31.55)	7.26 (8.51)
15	2.38	58.55	33.68	7.77

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 3				
1	1.66	48.54	40.27	11.19
2	1.94	48.12	41.33	10.55
3	2.04	49.61	39.48	10.91
4	2.54	50.63	40.14	9.23
5	2.46	51.13	40.74	8.13
6	2.49	53.71 (53.02)	38.03 (37.33)	8.26 (9.65)
7	2.32	55.12	37.59	7.29
8	2.45	55.32	36.81	7.87
9	2.36	56.14	34.93	8.93
10	2.43	58.77	32.87	8.36
11	2.55	58.54	32.71	8.75
12	2.53	59.74	31.67	8.59
13	2.51	60.12 (59.64)	31.01 (30.41)	8.87 (9.95)
14	2.65	57.93	34.14	7.93
15	2.42	57.58	33.57	8.85

Temperature 40 °C

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 1				
1	1.92	51.42	39.95	8.63
2	2.34	53.26	37.92	8.82
3	2.19	53.32	39.09	7.59
4	2.31	54.13	36.95	8.92
5	2.67	55.34 (54.86)	35.52 (34.80)	9.14 (10.34)
6	2.50	55.31	35.85	8.84
7	2.11	57.63	35.03	7.34
8	2.33	58.74	32.56	8.70
9	2.41	58.36	33.89	7.75
10	2.02	59.89	31.63	8.48
11	2.13	59.59	30.66	9.75
12	2.47	59.54	33.17	7.29
13	2.68	61.93	30.28	7.79
14	2.74	59.65	32.94	7.41
15	2.54	58.06	35.09	6.85

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 2				
1	1.49	52.49	38.92	8.59
2	1.57	53.17	38.36	8.47
3	1.74	53.20	39.67	7.13
4	2.31	53.19 (52.53)	37.88 (37.16)	8.93 (10.31)
5	2.26	54.26	38.12	7.62
6	2.38	54.31	38.58	7.11
7	2.45	55.54	36.89	7.57
8	2.47	57.91	33.46	8.63
9	2.43	58.55	32.62	8.83
10	2.43	59.13	33.77	7.10
11	2.59	60.47 (59.36)	32.26 (31.52)	7.27 (9.12)
12	2.53	61.31	30.39	8.30
13	2.93	58.39	33.22	8.39
14	2.74	59.36	32.94	7.70
15	2.61	58.75	34.90	6.35
Loading 3				
1	1.47	52.33	39.04	8.63
2	1.84	53.25	38.21	8.54
3	1.9	54.56	37.02	8.42
4	2.07	54.39	38.36	7.25
5	2.38	56.06	35.36	8.58
6	2.42	56.72	33.97	9.31
7	2.32	57.32	34.54	8.14
8	2.53	58.35	33.76	7.89
9	2.58	59.52	32.19	8.29

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
10	2.61	59.34 (58.62)	32.83 (32.13)	7.83 (9.25)
11	2.72	60.61	32.04	7.35
12	2.68	60.17	31.65	8.18
13	2.85	59.35	32.82	7.83
14	2.75	59.62	33.87	6.51
15	2.68	58.51	34.79	6.70

Temperature 45 °C

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 1				
1	0.78	39.31	49.14	11.55
2	1.04	44.19	44.23	11.58
3	1.16	43.90	44.50	11.60
4	1.52	43.13	44.45	12.45
5	1.04	45.38	43.08	11.54
6	1.46	45.43	42.83	11.74
7	1.34	45.87	43.30	10.83
8	1.04	45.93	43.93	10.14
9	1.42	44.46	44.44	11.10
10	1.00	46.25	42.48	11.27
11	1.18	45.85	43.33	10.82
12	1.13	45.62	43.27	11.11
13	1.05	46.54	42.71	10.75
14	1.13	45.35	43.36	11.29
15	1.25	45.82	42.65	11.53

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
16	1.50	46.11 (45.93)	42.76 (42.01)	11.13 (12.06)
17	1.45	48.70	40.82	10.48
18	1.52	45.05	43.65	11.30
19	1.21	47.56	41.59	10.85
20	1.47	47.48	40.90	11.62
21	1.98	49.52	39.71	10.77
22	1.95	50.39	38.78	10.83
23	1.47	50.79 (50.02)	39.03 (38.35)	10.18 (11.63)
24	1.75	48.38	42.54	9.08
25	1.44	48.02	42.23	9.75
Loading 2				
1	0.76	40.36	48.07	11.57
2	1.08	43.74	44.41	11.85
3	1.04	42.49	45.88	11.63
4	1.52	43.19	43.99	12.82
5	1.06	43.17 (42.94)	45.72 (45.01)	11.11 (11.05)
6	1.42	44.26	43.97	11.77
7	1.51	43.06	44.37	12.57
8	1.46	44.74	44.07	11.19
9	1.62	45.54	44.15	10.31
10	1.08	44.42	45.32	10.26
11	1.37	44.46	44.26	11.28
12	1.08	45.19	43.93	10.88
13	1.57	45.91	43.92	10.17
14	1.24	46.55	43.25	10.20

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
15	1.04	45.23	43.61	11.61
16	1.15	45.13	43.55	11.32
17	1.72	48.26	40.24	11.5
18	1.01	46.29	42.32	11.39
19	1.68	48.87 (48.06)	40.50 (39.92)	10.63 (12.02)
20	1.64	50.93	38.64	10.43
21	1.70	49.75	39.87	10.38
22	1.28	50.59	37.59	11.82
23	1.02	49.90	39.76	10.34
24	1.33	47.13	43.58	9.29
25	1.56	46.87	44.90	8.23
Loading 3				
1	0.77	41.21	47.48	11.31
2	1.01	42.01	45.80	12.19
3	1.12	43.60	45.02	11.38
4	1.34	42.83	45.74	11.43
5	1.61	44.27	45.27	10.46
6	1.44	43.46	45.29	11.25
7	1.58	44.90	43.56	11.54
8	1.67	45.41 (44.76)	43.24 (42.48)	11.35 (12.76)
9	1.37	45.26	42.57	12.17
10	1.69	44.72	43.40	11.88
11	1.02	45.21	44.56	10.23
12	1.51	45.24	43.47	11.29
13	1.16	45.78	42.50	11.72

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
14	1.58	45.57	42.99	11.44
15	1.21	46.10	43.61	10.29
16	1.61	46.54	43.14	10.32
17	1.11	47.35	42.08	10.57
18	1.06	46.49	42.35	11.16
19	1.42	47.24	40.98	11.78
20	1.67	49.33	39.61	11.06
21	1.34	50.28	37.97	11.75
22	1.14	50.73	38.66	10.61
23	1.69	49.16	40.81	10.03
24	1.14	49.46	40.99	9.55
25	1.37	47.25	43.78	8.97

Temperature 50 ^{o}C

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 1				
1	2.76	56.57	36.04	7.39
2	2.92	57.45	34.94	7.61
3	2.86	56.39	35.78	7.83
4	2.91	57.71 (57.93)	35.16 (34.48)	7.13 (7.59)
5	2.83	57.77	34.84	7.39
6	2.73	57.56	34.91	7.53
7	3.19	58.92	34.69	6.39
8	3.04	60.19	32.44	7.37
9	3.31	59.63	32.63	7.74
10	3.84	58.49	34.80	6.71

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
11	3.64	57.38	36.51	6.11
12	3.41	57.41	36.32	6.27
Loading 2				
1	2.23	57.48	35.33	7.19
2	2.16	56.37	35.98	7.65
3	2.39	57.69	34.92	7.39
4	2.52	57.84	34.63	7.53
5	3.04	58.74	33.54	7.72
6	3.58	59.91 (59.17)	33.83 (33.06)	6.26 (7.77)
7	3.31	58.20	34.65	7.15
8	3.46	59.17	34.24	6.59
9	3.66	59.49	33.30	7.21
10	3.29	58.14	34.63	7.23
11	3.83	57.86	35.82	6.32
12	3.64	56.97	36.67	6.36
Loading 3				
1	2.35	56.87	35.59	7.54
2	2.38	57.93	34.21	7.86
3	2.72	56.77	36.15	7.08
4	2.67	57.47	35.38	7.15
5	3.15	58.16	34.56	7.28
6	3.21	58.67	34.97	6.36
7	3.39	58.30	34.95	6.75
8	3.47	59.29	34.12	6.59
9	3.52	58.87	34.61	6.52
10	3.79	57.93	35.96	6.11
11	3.66	57.85	35.8	6.35
12	3.45	56.62	36.96	6.42

Temperature 55 °C

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 1				
1	2.65	59.49	31.06	9.45
2	3.11	59.21	32.24	8.55
3	3.08	58.84	32.51	8.65
4	3.47	60.54	31.40	8.06
5	3.38	59.93	32.44	7.63
6	3.42	59.84	31.37	8.79
7	3.98	60.34	31.91	7.75
8	3.71	61.32	30.32	8.36
9	4.18	61.13	31.20	7.67
10	3.71	60.34	31.92	7.74
11	3.45	59.24	33.49	7.27
Loading 2				
1	2.93	59.28	31.64	9.08
2	3.23	58.83	32.28	8.89
3	3.23	59.82	32.27	7.91
4	3.28	60.59	31.00	8.41
5	3.34	59.92	32.33	7.75
6	3.54	60.77	31.94	7.29
7	3.67	60.48	32.19	7.33
8	3.81	60.36	31.39	8.25
9	4.01	59.99	32.45	7.56
10	3.56	60.95	31.85	7.20
11	3.31	60.28	32.67	7.05

Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 3				
1	2.61	58.56	32.38	9.06
2	3.14	59.62	31.75	8.63
3	3.37	59.89	32.28	7.83
4	3.46	60.29	32.18	7.53
5	3.52	60.30	32.38	7.32
6	3.56	60.57	31.19	8.24
7	3.73	60.32	31.94	7.74
8	3.78	60.21	31.36	8.43
9	3.97	59.94	32.02	8.04
10	3.68	59.43	33.15	7.42
11	3.56	59.51	33.24	7.25

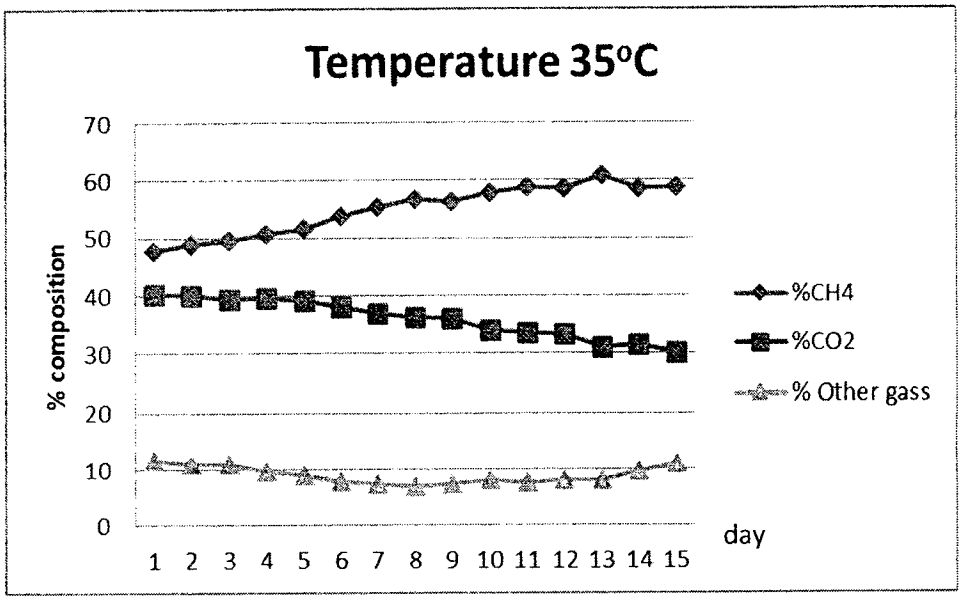
Temperature 60 °C

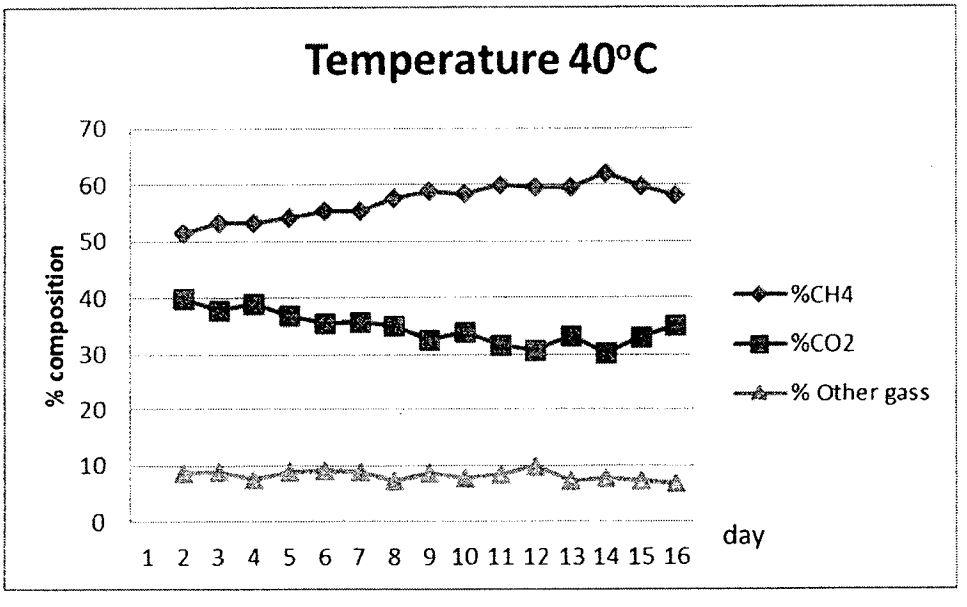
Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 1				
1	1.14	48.83	37.0	14.14
2	1.37	49.18	37.47	13.35
3	1.68	48.34	38.07	13.59
4	1.17	48.61	38.20	13.19
5	1.22	48.17	38.91	12.92
6	1.27	48.25	39.63	12.12
7	1.49	49.82	38.60	11.58
8	1.89	49.21	39.40	11.39
9	1.72	49.58	39.51	10.91
10	2.05	50.31	39.54	10.15

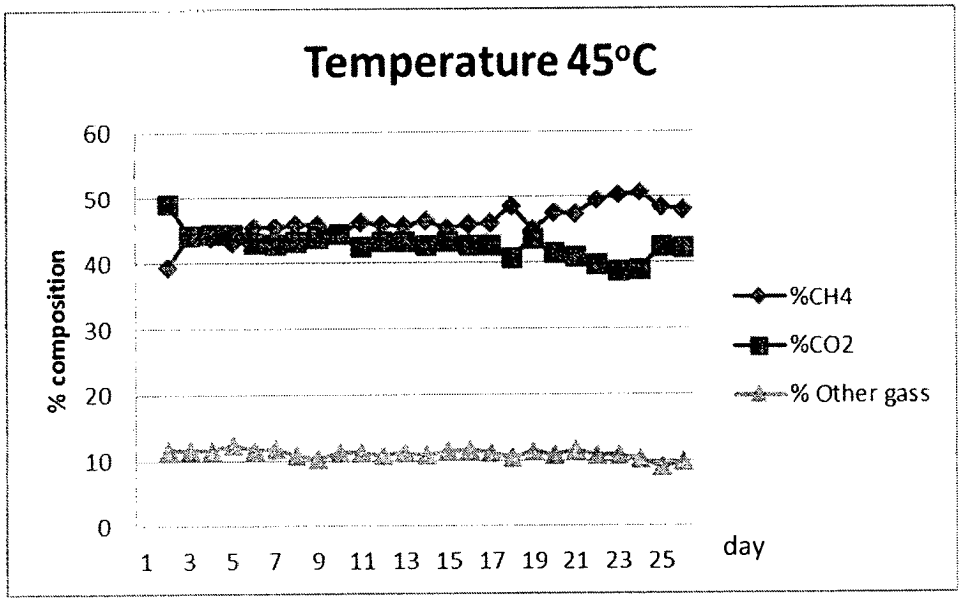
Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
11	1.83	50.14	38.98	10.88
12	1.82	49.83	39.34	10.83
13	2.10	50.15	38.47	11.38
14	2.23	50.19	37.95	11.86
15	2.43	52.41	37.28	10.31
16	2.50	52.11	36.78	11.11
17	2.31	50.21	37.92	11.87
18	2.27	49.45	39.06	11.49
19	2.03	48.53	40.77	10.7
Loading 2				
1	1.27	48.14	37.40	14.46
2	1.38	48.45	37.87	13.68
3	1.59	48.73	37.54	13.73
4	1.74	49.40	38.19	12.41
5	1.61	49.83	37.82	12.35
6	1.54	49.93	38.16	11.91
7	1.73	48.76	38.90	12.34
8	1.65	49.37	38.87	11.76
9	1.71	49.72	38.24	12.04
10	1.91	50.52	37.13	12.35
11	1.64	50.61	37.45	11.94
12	1.98	50.75	38.92	10.33
13	2.11	51.59	37.34	11.07
14	2.08	52.06	37.44	10.50
15	2.13	51.63	37.14	11.23
16	2.23	51.57	36.86	11.57
17	2.22	49.91	38.72	11.37
18	2.03	49.17	40.06	10.77
19	1.85	50.64	38.62	10.74

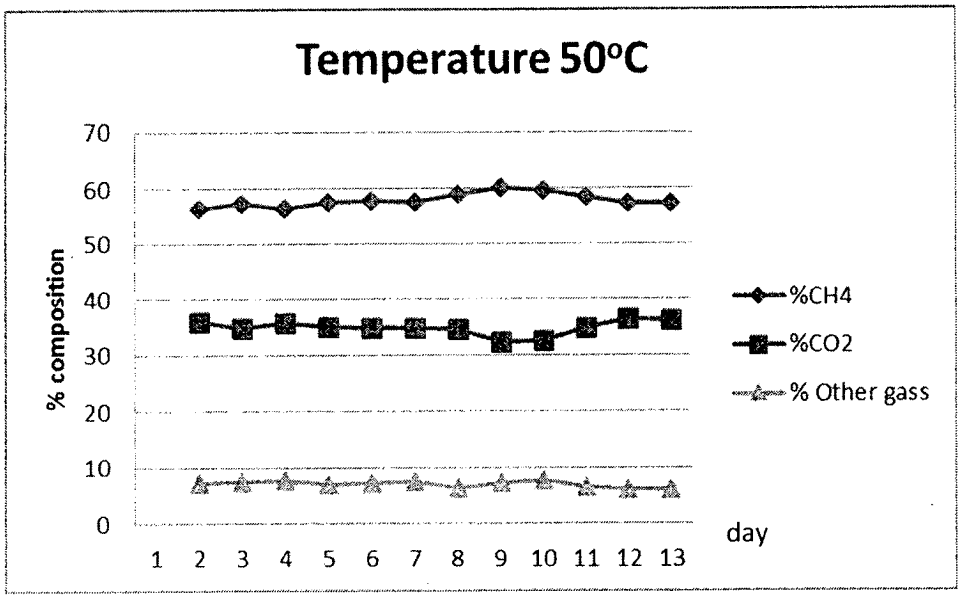
Days	Daily biogas production (L)	%CH_4	%CO_2	% Other gases
Loading 3				
1	1.39	49.34	36.47	14.19
2	1.47	49.62	37.00	13.38
3	1.43	50.50	36.07	13.43
4	1.31	50.28	36.66	13.06
5	1.56	50.86	35.89	13.25
6	1.78	50.12	37.34	12.54
7	1.66	49.72	37.93	12.35
8	1.79	50.85	37.10	12.05
9	1.73	50.14	36.96	12.90
10	1.85	50.02	37.91	12.07
11	2.02	51.31	36.42	12.27
12	1.93	51.11	36.02	12.87
13	2.09	51.09	36.16	12.75
14	2.10	50.92	36.79	12.29
15	2.13	50.56	38.26	11.18
16	2.24	50.73	38.04	11.23
17	2.12	49.99	39.72	11.29
18	2.07	49.82	39.53	10.65
19	1.98	49.31	39.36	11.33

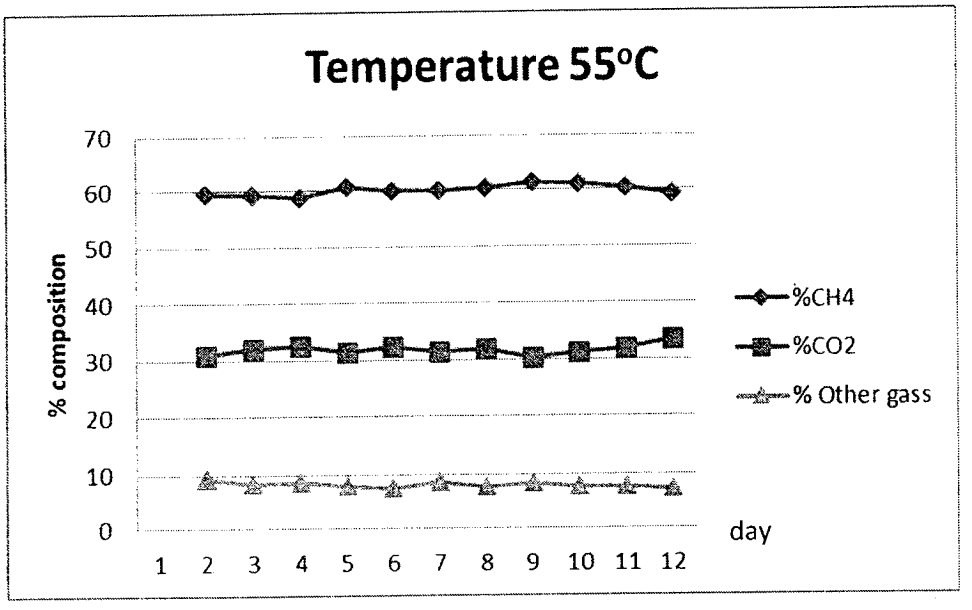
Biogas composition

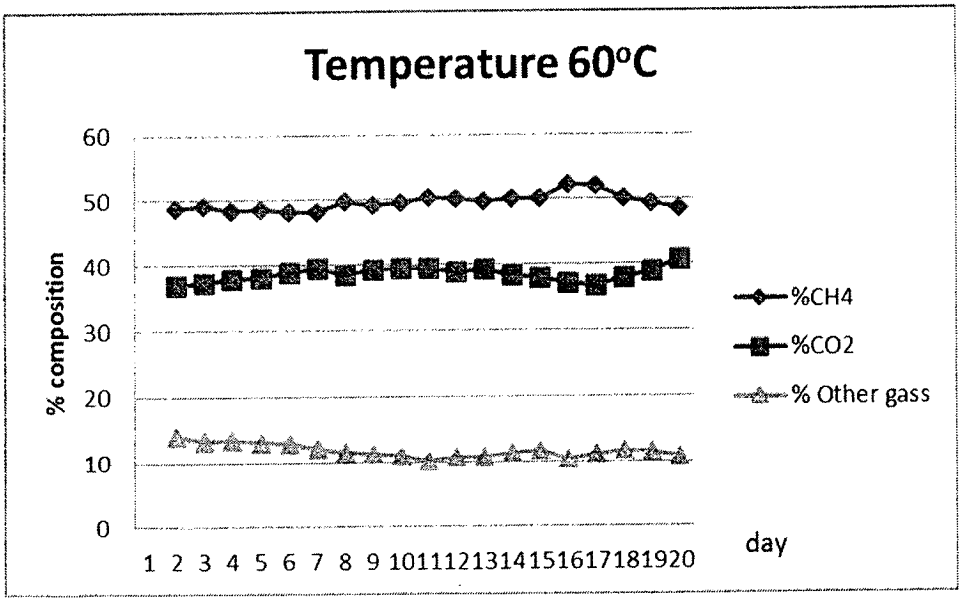





Temperature 45°C
% composition
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25
day
%CH4
%CO2
% Other gass


Temperature 50°C
% composition
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13
day
%CH4
%CO2
% Other gass


Temperature 55°C
70
60
50
40
30
20
10
0
% composition
1 2 3 4 5 6 7 8 9 10 11 12
day
%CH4
%CO2
% Other gass


Temperature 60°C
60
50
40
30
20
10
0
% composition
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
day
%CH4
%CO2
% Other gass

Comparison Gas analyzer and GC

Temperature 35 °C

Days	Analysis	%CH_4	%CO_2	% Other gases
Loading 1				
8	Gas analyzer	56.73	36.25	7.02
	GC	55.09	36.99	7.92
15	Gas analyzer	58.83	30.12	11.05
	GC	58.01	30.89	11.1
Loading 2				
7	Gas analyzer	54.95	36.56	8.49
	GC	54.13	37.25	8.62
14	Gas analyzer	60.62	32.12	7.26
	GC	59.94	31.55	8.51
Loading 3				
6	Gas analyzer	53.71	38.03	8.26
	GC	53.02	37.33	9.65
13	Gas analyzer	60.12	31.01	8.87
	GC	59.64	30.41	9.95

Error : CH_4 0.85 %

CO_2 0.67 %

Other gases 0.8 %