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APPENDICES

Appendix A Calibration Curves

Table A1 Calibration curve for hydrogen (H₂)

Volume of hydrogen (ml)	Peak area
0.02	16,313
0.04	58,770
0.08	180,674
0.1	226,743
0.2	427,198
0.4	778,509

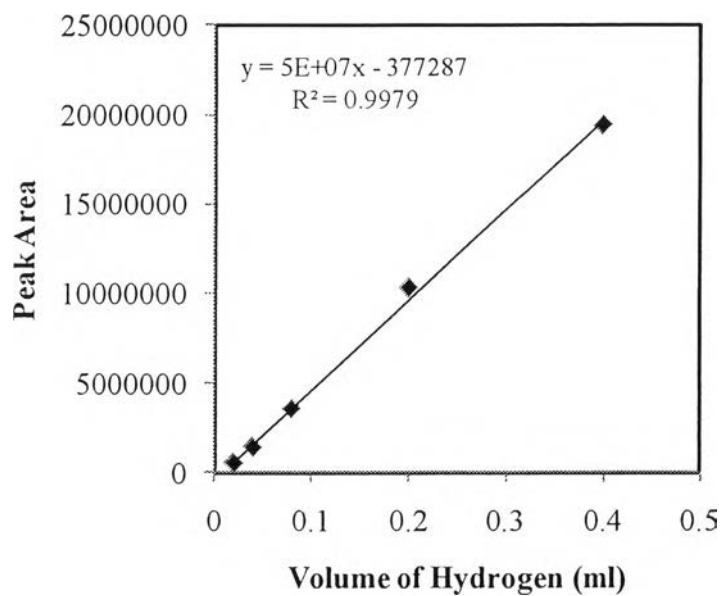


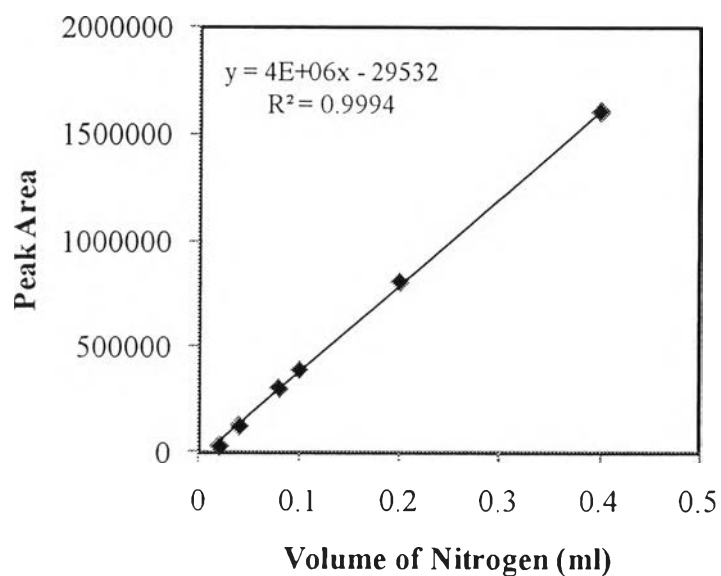
Figure A1 The relationship between volume of hydrogen (H₂) and peak area.

Equation

$$\text{Amount of hydrogen} = \frac{\text{Peak area} + 377287}{5 \times 10^7}$$

Table A2 Calibration curve for nitrogen

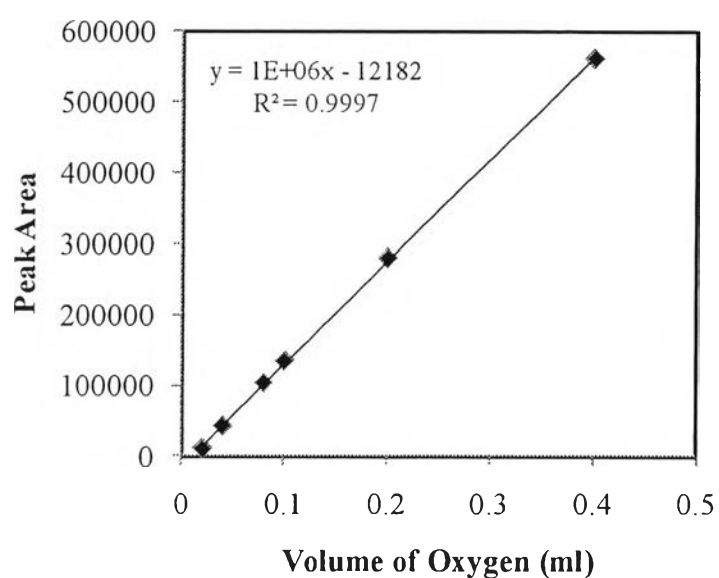
Volume of nitrogen (ml)	Peak area
0.02	34,210
0.04	128,767
0.08	305,287
0.1	393,916
0.2	809,433
0.4	1,602,475

**Figure A2** The relationship between volume of nitrogen (N_2) and peak area.**Equation**

$$\text{Amount of nitrogen} = \frac{\text{Peak area} + 29532}{4 \times 10^6}$$

Table A3 Calibration curve for oxygen

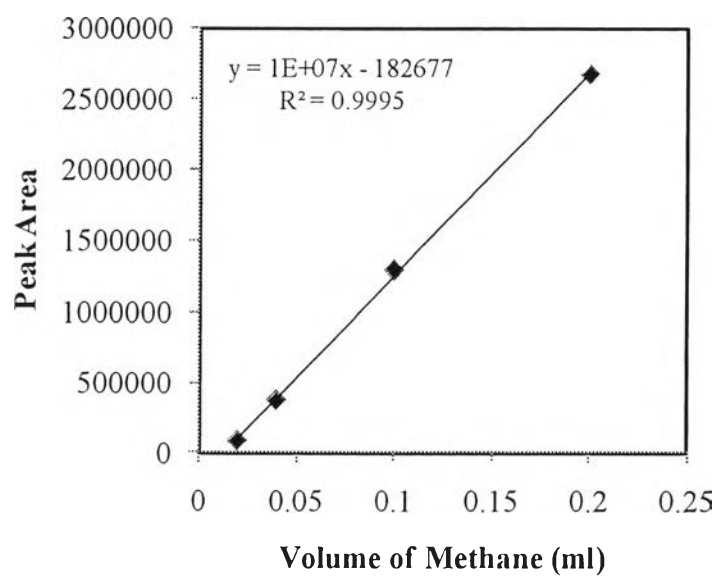
Volume of oxygen (ml)	Peak area
0.02	12,286
0.04	43,995
0.08	104,342
0.1	135,546
0.2	280,220
0.4	562,001

**Figure A3** The relationship between volume of oxygen (O₂) and peak area.**Equation**

$$\text{Amount of oxygen} = \frac{\text{Peak area} + 12182}{1 \times 10^6}$$

Table A4 Calibration curve for methane (CH₄)

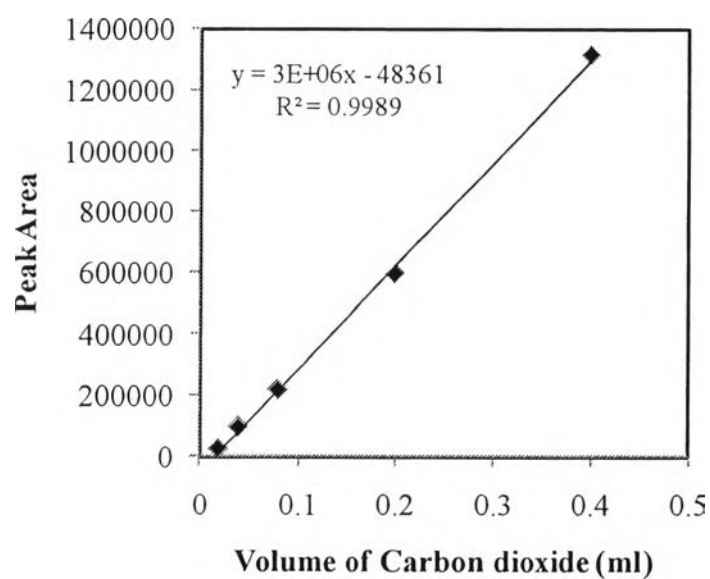
Volume of methane (ml)	Peak area
0.02	92,517
0.04	381,106
0.1	1,293,552
0.2	2,674,654

**Figure A4** The relationship between volume of methane (CH₄) and peak area.**Equation**

$$\text{Amount of methane} = \frac{\text{Peak area} + 182677}{1 \times 10^7}$$

Table A5 Calibration curve for carbon dioxide (CO₂)

Volume of carbon dioxide (ml)	Peak area
0.02	26,118
0.04	97,539
0.08	220,122
0.2	596,414
0.4	1,315,885

**Figure A5** The relationship between volume of carbon dioxide (CO₂) and peak area.**Equation**

$$\text{Amount of carbon dioxide} = \frac{\text{Peak area} + 48361}{3 \times 10^6}$$

Appendix B Preparation of 5 wt./vol.% NaOH Solution for pH-controlled System

Preparation of NaOH at concentration of 5 wt./vol.%

$$= \frac{5 \text{ g}}{100 \text{ ml}} = 50 \frac{\text{g}}{\text{l}}$$

Appendix C Volatile Fatty Acids (VFA) Quantification by Distillation Method

C 1. Acetic Acids Stock Solution Preparation for Recovery Factor (f) Determination

Concentration of fresh acetic acid (liquid)	=	99.7%
Density of acetic acid	=	1.07 g/ml
Molecular weight of acetic acid	=	60

Determination of fresh acetic acids concentration in term of molar

$$= \frac{0.997 \text{ L of acetic acid}}{\text{L of solution}} \times \frac{1.07 \text{ g of acetic acid}}{\text{mL of acetic acid}} \times \frac{1 \text{ mol of acetic acid}}{60 \text{ g of acetic acid}}$$

$$= 17.78 \text{ M}$$

Preparation of acetic acid at concentration of 2,000 mg/L

$$= 2,000 \frac{\text{mg of acetic acid}}{\text{L of solution}} \times \frac{1 \text{ mole of acetic acid}}{60 \text{ g of acetic acid}}$$

$$= 0.0333 \text{ M}$$

Dilution of acetic acid

$$N_1 V_1 = N_2 V_2$$

$$V_1 = \frac{N_2 V_2}{N_1}$$

$$= \frac{(0.0333 \times 1)}{17.78}$$

$$= 1.873 \times 10^{-3} \text{ L}$$

C 2. Standard Sodium Hydroxide (0.1 M) Preparation

Concentration of fresh NaOH (solid)	=	99%
Molecular weight of acetic acid	=	40

Preparation of acetic acid at concentration of 0.1 M

$$= \frac{0.1 \text{ mol}}{1 \text{ L}} \times \frac{40 \text{ g}}{1 \text{ mol}} \times \frac{100}{99}$$

$$= 4.04 \text{ g}$$

C 3. Recovery Factor (f) Determination

Distill 150 ml of 0.0333 M of acetic acid in distillation apparatus

Calculate the recovery factor

$$f = \frac{a}{b}$$

where

a = volatile acid concentration recovered in distillate, mg/L

b = volatile acid concentration in standard solution used, mg/L

Find volatile acid concentration recovered in distillate by titration with 0.1 M of NaOH (MW of acetic acid = 60.5)

1) Distillate	50 ml	NaOH	11.7 ml	
Used NaOH		=		$11.7 \times 10^{-3} \times 0.1$
		=		1.17×10^{-3} mol
Acetic acid in distillate		=		1.17×10^{-3} mol
		=		$1.17 \times 10^{-3} \times 60.5$
		=		0.07 g
Concentration of acetic acid in distillate		=		0.07/50
		=		1.405×10^{-3} g/ml
		=		1,405 mg/l
2) Distillate	25 ml	NaOH	5.7 ml	
Used NaOH		=		$5.7 \times 10^{-3} \times 0.1$
		=		5.7×10^{-4} mol
Acetic acid in distillate		=		5.7×10^{-4} mol
		=		$5.7 \times 10^{-4} \times 60.5$
		=		0.034 g
Concentration of acetic acid in distillate		=		0.034/25
		=		1.368×10^{-3} g/ml
		=		1,368 mg/l
Average		=		1,387 mg/l
Recovery factor (f)		=		$1,387/2,000$
		=		0.6935

Appendix D Raw Data of Effect of COD Loading Rate on Hydrogen Production

D 1. COD loading rate = 5 kg/ m³d

pH = 5.5

Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.084	0.089	0.173	0	48.55	51.45
2	0	0.094	0.103	0.197	0	47.80	52.20
3	0	0.101	0.100	0.201	0	50.40	49.60
4	0	0.122	0.127	0.249	0	49.00	51.00
5	0	0.114	0.121	0.235	0	48.51	51.49
6	0	0.124	0.123	0.246	0	50.16	49.84
7	0	0.093	0.094	0.187	0	49.52	50.48
8	0	0.124	0.120	0.244	0	50.96	49.04
9	0	0.114	0.117	0.232	0	49.33	50.67
10	0	0.120	0.130	0.250	0	48.06	51.94
Avg.	0	0.109	0.112	0.221	0	49.23	50.77

Gas production rate	=	2.28	l/d
Methane production rate	=	1.12	l/d
Specific methane production rate	=	3.24	ml CH ₄ /g MLVSS d
VFA Concentration	=	11,015	mg/l as acetic acid
Methane yield	=	60.33	ml CH ₄ /g COD removed
COD removal efficiency	=	22.51	%
MLVSS	=	14,420	mg/l
TSS	=	7,240	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	2,055
Acetic acid	1,521
Propionic acid	2,406
Butyric acid	2,678
Valeric acid	2,353

D 2. COD loading rate = 10 kg/ m³d

pH = 5.5

Temperature = 37 °C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.124	0.123	0.247	0	50.20	49.80
2	0	0.122	0.123	0.246	0	49.82	50.18
3	0	0.135	0.140	0.275	0	49.00	51.00
4	0	0.118	0.127	0.245	0	48.16	51.84
5	0	0.138	0.137	0.275	0	50.18	49.82
6	0	0.139	0.139	0.278	0	50.02	49.98
7	0	0.164	0.153	0.318	0	51.76	48.24
8	0	0.174	0.148	0.322	0	54.04	45.96
9	0	0.166	0.170	0.336	0	49.33	50.67
10	0	0.136	0.148	0.284	0	47.94	52.06
Avg.	0	0.142	0.141	0.283	0	50.05	49.95

Gas production rate	=	5.58	l/d
Methane production rate	=	2.79	l/d
Specific methane production rate	=	6.46	ml CH ₄ /g MLVSS d
VFA concentration	=	12,106	mg/l as acetic acid
Methane yield	=	81.21	ml CH ₄ /g COD removed
COD removal efficiency	=	28.33	%
MLVSS	=	18,020	mg/l
TSS	=	6,760	mg/l

Distillated sample 100 µl + Internal standard (n-propanol 3,000 ppm) 100 µl

VFA	Concentration (ppm)
Ethanol	2,580
Acetic acid	1,745
Propionic acid	2,231
Butyric acid	2,981
Valeric acid	2,557

D 3. COD loading rate = 20 kg/ m³d

pH = 5.5

Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.204	0.206	0.410	0	49.81	50.19
2	0	0.217	0.201	0.418	0	52.00	48.00
3	0	0.241	0.223	0.464	0	51.92	48.08
4	0	0.192	0.185	0.377	0	50.96	49.04
5	0	0.180	0.163	0.342	0	52.47	47.53
6	0	0.220	0.197	0.417	0	52.77	47.23
7	0	0.187	0.178	0.366	0	51.24	48.76
8	0	0.194	0.166	0.360	0	53.85	46.15
9	0	0.239	0.234	0.473	0	50.56	49.44
10	0	0.240	0.225	0.465	0	51.71	48.29
Avg.	0	0.211	0.198	0.409	0	51.73	48.27

Gas production rate	=	13.80	l/d
Methane production rate	=	7.14	l/d
Specific methane production rate	=	13.88	ml CH ₄ /g MLVSS d
VFA concentration	=	12,544	mg/l as acetic acid
Methane yield	=	118.72	ml CH ₄ /g COD removed
COD removal efficiency	=	37.37	%
MLVSS	=	21,427	mg/l
TSS	=	5,260	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	2,954
Acetic acid	1,752
Propionic acid	2,012
Butyric acid	3,031
Valeric acid	2,793

D4. COD loading rate = 48 kg/ m³d

pH = 5.5

Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.253	0.170	0.423	0	59.84	40.16
2	0	0.277	0.110	0.387	0	71.55	28.45
3	0	0.247	0.100	0.347	0	71.15	28.85
4	0	0.253	0.120	0.373	0	67.86	32.14
5	0	0.259	0.160	0.419	0	61.79	38.21
6	0	0.239	0.140	0.379	0	63.08	36.92
7	0	0.230	0.150	0.380	0	60.53	39.47
8	0	0.277	0.150	0.427	0	64.84	35.16
9	0	0.273	0.160	0.433	0	63.07	36.93
10	0	0.201	0.134	0.335	0	60.00	40.00
Avg.	0	0.251	0.139	0.390	0	64.40	35.60

Gas production rate	=	28.53	l/d
Methane production rate	=	18.37	l/d
Specific Methane production rate	=	27.67	ml CH ₄ /g MLVSS d
VFA concentration	=	13,179	mg/l as acetic acid
Methane yield	=	164.24	ml CH ₄ /g COD removed
COD removal efficiency	=	41.74	%
MLVSS	=	27,667	mg/l
TSS	=	5,024	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	3,245
Acetic acid	1,834
Propionic acid	1,710
Butyric acid	3,347
Valeric acid	3,042

D 5. COD loading rate = 60 kg/ m³d

pH = 5.5

Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.224	0.188	0.412	0	54.35	45.65
2	0	0.227	0.217	0.444	0	51.10	48.90
3	0	0.257	0.239	0.496	0	51.81	48.19
4	0	0.213	0.218	0.431	0	49.44	50.56
5	0	0.220	0.200	0.420	0	52.38	47.62
6	0	0.209	0.208	0.417	0	50.06	49.94
7	0	0.218	0.198	0.416	0	52.35	47.65
8	0	0.226	0.206	0.432	0	52.28	47.72
9	0	0.199	0.188	0.386	0	51.42	48.58
10	0	0.230	0.187	0.417	0	55.06	44.94
Avg.	0	0.222	0.205	0.427	0	52.03	47.97

Gas production rate	=	24.04	l/d
Methane production rate	=	12.51	l/d
Specific methane production rate	=	20.49	ml CH ₄ /g MLVSS d
VFA concentration	=	14,047	mg/l as acetic acid
Methane yield	=	65.79	ml CH ₄ /g COD removed
COD removal efficiency	=	20.78	%
MLVSS	=	25,432	mg/l
TSS	=	5,457	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	3,454
Acetic acid	2,078
Propionic acid	1,687
Butyric acid	3,575
Valeric acid	3,252

D 6. COD loading rate = 120 kg/ m³d pH = 5.5 Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.157	0.179	0.337	0	46.73	53.27
2	0	0.202	0.213	0.416	0	48.70	51.30
3	0	0.163	0.188	0.351	0	46.55	53.45
4	0	0.137	0.162	0.299	0	45.82	54.18
5	0	0.173	0.194	0.368	0	47.18	52.82
6	0	0.200	0.198	0.398	0	50.30	49.70
7	0	0.166	0.201	0.367	0	45.23	54.77
8	0	0.202	0.233	0.435	0	46.37	53.63
9	0	0.226	0.254	0.480	0	47.05	52.95
10	0	0.240	0.265	0.506	0	47.53	52.47
Avg.	0	0.187	0.209	0.396	0	47.15	52.85

Gas production rate	=	18.55	l/d
Methane production rate	=	8.75	l/d
Specific methane production rate	=	14.50	ml CH ₄ /g MLVSS d
VFA concentration	=	15,011	mg/l as acetic acid
Methane yield	=	21.32	ml CH ₄ /g COD removed
COD removal efficiency	=	14.51	%
MLVSS	=	25,138	mg/l
TSS	=	5,825	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	3,796
Acetic acid	2,188
Propionic acid	1,644
Butyric acid	4,151
Valeric acid	4,004

D 7. COD loading rate = 180 kg/ m³d pH = 5.5 Temperature = 37 °C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0.004	0.163	0.266	0.433	0.95	37.64	61.42
2	0.005	0.148	0.228	0.381	1.36	38.82	59.81
3	0.004	0.127	0.203	0.334	1.23	38.01	60.76
4	0.004	0.138	0.250	0.392	1.00	35.21	63.79
5	0.002	0.146	0.270	0.418	0.55	34.90	64.55
6	0.004	0.171	0.235	0.410	1.07	41.67	57.26
7	0.003	0.155	0.265	0.423	0.80	36.61	62.59
8	0.004	0.167	0.274	0.445	0.83	37.55	61.61
9	0.004	0.146	0.226	0.376	1.09	38.82	60.09
10	0.003	0.174	0.219	0.396	0.81	43.92	55.28
Avg.	0.004	0.154	0.244	0.401	0.94	38.15	60.91

Gas production rate	=	10.72	l/d
Methane production rate	=	4.09	l/d
Hydrogen production rate	=	0.10	l/d
Specific Methane production rate	=	7.40	ml CH ₄ /g MLVSS d
Specific Hydrogen production rate	=	1.08	ml H ₂ /g MLVSS d
VFA concentration	=	15,854	mg/l as acetic acid
Methane yield	=	6.47	ml CH ₄ /g COD removed
Hydrogen yield	=	0.16	ml H ₂ /g COD removed
COD removal efficiency	=	12.18	%
MLVSS	=	23,037	mg/l
TSS	=	6,136	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	3,796
Acetic acid	2,396
Propionic acid	1,506
Butyric acid	4,151
Valeric acid	4,004

D 8. COD loading rate = 270 kg/ m³d

pH = 5.5

Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0.110	0.041	0.318	0.469	23.51	8.66	67.83
2	0.103	0.029	0.337	0.469	22.03	6.18	71.79
3	0.081	0.025	0.291	0.397	20.41	6.17	73.41
4	0.106	0.036	0.307	0.449	23.68	7.99	68.34
5	0.106	0.032	0.317	0.455	23.22	7.08	69.70
6	0.106	0.034	0.325	0.466	22.85	7.35	69.80
7	0.105	0.037	0.342	0.485	21.73	7.64	70.63
8	0.084	0.028	0.287	0.399	21.05	6.94	72.01
9	0.090	0.035	0.298	0.423	21.35	8.30	70.35
10	0.100	0.033	0.304	0.437	22.96	7.46	69.58
Avg.	0.099	0.033	0.313	0.445	22.15	7.37	70.48

Gas production rate	=	9.01	l/d
Methane production rate	=	0.66	l/d
Hydrogen production rate	=	2.00	l/d
Specific methane production rate	=	1.22	ml CH ₄ /g MLVSS d
Specific hydrogen production rate	=	21.27	ml H ₂ /g MLVSS d
VFA concentration	=	17,214	mg/l as acetic acid
Methane yield	=	0.74	ml CH ₄ /g COD removed
Hydrogen yield	=	2.22	ml H ₂ /g COD removed
COD removal efficiency	=	9.20	%
MLVSS	=	22,600	mg/l
TSS	=	6,213	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	3,806
Acetic acid	2,537
Propionic acid	1,409
Butyric acid	5,002
Valeric acid	4,459

Appendix E Raw Data of Effect of COD Loading Rate on Methane Production

E1. COD loading rate = 5 kg/ m³d Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.387	0.091	0.479	0	80.94	19.06
2	0	0.341	0.080	0.420	0	81.08	18.92
3	0	0.331	0.081	0.412	0	80.36	19.64
4	0	0.381	0.110	0.492	0	77.55	22.45
5	0	0.354	0.098	0.452	0	78.25	21.75
6	0	0.360	0.110	0.470	0	76.60	23.40
7	0	0.347	0.097	0.444	0	78.15	21.85
8	0	0.325	0.074	0.399	0	81.45	18.55
9	0	0.373	0.122	0.495	0	75.35	24.65
10	0	0.353	0.097	0.450	0	78.44	21.56
Avg.	0	0.355	0.096	0.451	0	78.81	21.19

Gas production rate	=	5.66	l/d
Methane production rate	=	4.46	l/d
Specific methane production rate	=	12.89	ml CH ₄ /g MLVSS d
VFA Concentration	=	343	mg/l as acetic acid
Methane yield	=	288.01	ml CH ₄ /g COD removed
COD removal efficiency	=	58.35	%
MLVSS	=	12,620	mg/l
TSS	=	5,500	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	128
Acetic acid	70
Propionic acid	77
Butyric acid	35
Valeric acid	32

E2. COD loading rate = 10 kg/ m³d Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.373	0.098	0.471	0	79.19	20.81
2	0	0.337	0.110	0.447	0	75.39	24.61
3	0	0.389	0.099	0.488	0	79.71	20.29
4	0	0.378	0.086	0.464	0	81.47	18.53
5	0	0.356	0.104	0.460	0	77.39	22.61
6	0	0.381	0.097	0.478	0	79.71	20.29
7	0	0.399	0.100	0.499	0	79.96	20.04
8	0	0.400	0.100	0.500	0	80.00	20.00
9	0	0.374	0.096	0.470	0	79.57	20.43
10	0	0.385	0.078	0.463	0	83.15	16.85
Avg.	0	0.377	0.097	0.474	0	79.56	20.44

Gas production rate	=	11.52	l/d
Methane production rate	=	9.17	l/d
Specific methane production rate	=	21.19	ml CH ₄ /g MLVSS d
VFA Concentration	=	325	mg/l as acetic acid
Methane yield	=	327.32	ml CH ₄ /g COD removed
COD removal efficiency	=	59.30	%
MLVSS	=	15,940	mg/l
TSS	=	5,060	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	124
Acetic acid	73
Propionic acid	32
Butyric acid	29
Valeric acid	124

E3. COD loading rate = 20 kg/ m³d Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.330	0.080	0.410	0	80.49	19.51
2	0	0.287	0.066	0.353	0	81.30	18.70
3	0	0.401	0.097	0.498	0	80.51	19.49
4	0	0.351	0.104	0.455	0	77.14	22.86
5	0	0.401	0.094	0.495	0	81.01	18.99
6	0	0.321	0.078	0.399	0	80.45	19.55
7	0	0.343	0.076	0.419	0	81.86	18.14
8	0	0.284	0.073	0.357	0	79.55	20.45
9	0	0.336	0.073	0.409	0	82.21	17.79
10	0	0.324	0.077	0.401	0	80.81	19.19
Avg.	0	0.338	0.082	0.420	0	80.50	19.50

Gas production rate	=	22.58	l/d
Methane production rate	=	18.18	l/d
Specific methane production rate	=	35.35	ml CH ₄ /g MLVSS d
VFA Concentration	=	310	mg/l as acetic acid
Methane yield	=	405.64	ml CH ₄ /g COD removed
COD removal efficiency	=	62.74	%
MLVSS	=	18,140	mg/l
TSS	=	4,113	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	122
Acetic acid	63
Propionic acid	71
Butyric acid	28
Valeric acid	25

E4. COD loading rate = 48 kg/ m³d Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.369	0.067	0.435	0	84.72	15.28
2	0	0.377	0.071	0.448	0	84.08	15.92
3	0	0.349	0.050	0.399	0	87.39	12.61
4	0	0.321	0.056	0.377	0	85.08	14.92
5	0	0.415	0.082	0.496	0	83.57	16.43
6	0	0.368	0.075	0.443	0	83.07	16.93
7	0	0.388	0.074	0.462	0	84.03	15.97
8	0	0.389	0.071	0.460	0	84.56	15.44
9	0	0.350	0.054	0.404	0	86.56	13.44
10	0	0.366	0.064	0.430	0	85.03	14.97
Avg.	0	0.369	0.066	0.436	0	84.81	15.19

Gas production rate	=	39.56	l/d
Methane production rate	=	33.33	l/d
Specific methane production rate	=	50.52	ml CH ₄ /g MLVSS d
VFA Concentration	=	239	mg/l as acetic acid
Methane yield	=	427.53	ml CH ₄ /g COD removed
COD removal efficiency	=	64.93	%
MLVSS	=	20,066	mg/l
TSS	=	3,160	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	99
Acetic acid	46
Propionic acid	51
Butyric acid	23
Valeric acid	19

E5. COD loading rate = 60 kg/ m³d Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.371	0.060	0.431	0	86.03	13.97
2	0	0.343	0.081	0.424	0	80.82	19.18
3	0	0.287	0.062	0.349	0	82.36	17.64
4	0	0.331	0.073	0.404	0	81.90	18.10
5	0	0.372	0.105	0.477	0	77.97	22.03
6	0	0.361	0.094	0.455	0	79.34	20.66
7	0	0.351	0.072	0.423	0	82.96	17.04
8	0	0.347	0.086	0.433	0	80.15	19.85
9	0	0.371	0.100	0.472	0	78.73	21.27
10	0	0.284	0.069	0.353	0	80.44	19.56
Avg.	0	0.342	0.080	0.422	0	81.07	18.93

Gas production rate	=	37.93	l/d
Methane production rate	=	30.76	l/d
Specific methane production rate	=	50.39	ml CH ₄ /g MLVSS d
VFA Concentration	=	336	mg/l as acetic acid
Methane yield	=	181.42	ml CH ₄ /g COD removed
COD removal efficiency	=	55.41	%
MLVSS	=	21,158	mg/l
TSS	=	3,300	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	130
Acetic acid	46
Propionic acid	74
Butyric acid	33
Valeric acid	30

E6. COD loading rate = 120 kg/ m³d Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.210	0.072	0.283	0	74.39	25.61
2	0	0.224	0.080	0.304	0	73.68	26.32
3	0	0.302	0.114	0.416	0	72.54	27.46
4	0	0.301	0.121	0.422	0	71.33	28.67
5	0	0.224	0.094	0.318	0	70.44	29.56
6	0	0.272	0.117	0.389	0	69.92	30.08
7	0	0.247	0.094	0.341	0	72.43	27.57
8	0	0.345	0.127	0.472	0	73.09	26.91
9	0	0.215	0.079	0.294	0	73.13	26.87
10	0	0.212	0.081	0.293	0	72.35	27.65
Avg.	0	0.255	0.098	0.353	0	72.33	27.67

Gas production rate	=	24.73	l/d
Methane production rate	=	17.89	l/d
Specific methane production rate	=	29.65	ml CH ₄ /g MLVSS d
VFA Concentration	=	431	mg/l as acetic acid
Methane yield	=	34.73	ml CH ₄ /g COD removed
COD removal efficiency	=	37.23	%
MLVSS	=	22,200	mg/l
TSS	=	3,476	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	167
Acetic acid	77
Propionic acid	84
Butyric acid	53
Valeric acid	49

E7. COD loading rate = 180 kg/ m³d Temperature = 37 °C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.234	0.211	0.445	0	52.58	47.42
2	0	0.242	0.201	0.443	0	54.63	45.37
3	0	0.242	0.192	0.434	0	55.76	44.24
4	0	0.238	0.202	0.440	0	54.09	45.91
5	0	0.244	0.196	0.440	0	55.45	44.55
6	0	0.277	0.211	0.488	0	56.76	43.24
7	0	0.243	0.215	0.458	0	53.06	46.94
8	0	0.201	0.195	0.396	0	50.76	49.24
9	0	0.249	0.200	0.449	0	55.46	44.54
10	0	0.239	0.204	0.443	0	53.95	46.05
Avg.	0	0.241	0.203	0.444	0	54.25	45.75

Gas production rate	=	20.10	l/d
Methane production rate	=	10.90	l/d
Specific methane production rate	=	19.72	ml CH ₄ /g MLVSS d
VFA Concentration	=	481	mg/l as acetic acid
Methane yield	=	10.97	ml CH ₄ /g COD removed
COD removal efficiency	=	21.41	%
MLVSS	=	23,280	mg/l
TSS	=	3,515	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	185
Acetic acid	82
Propionic acid	95
Butyric acid	64
Valeric acid	53

E8. COD loading rate = 270 kg/ m³d Temperature = 37°C

Days	Amount of each component (ml)			Total amount (ml)	Produced gas composition (%)		
	H ₂	CH ₄	CO ₂		H ₂	CH ₄	CO ₂
1	0	0.218	0.222	0.440	0	49.55	50.45
2	0	0.264	0.247	0.511	0	51.66	48.34
3	0	0.237	0.232	0.469	0	50.59	49.41
4	0	0.285	0.282	0.567	0	50.28	49.72
5	0	0.278	0.269	0.546	0	50.80	49.20
6	0	0.263	0.286	0.549	0	47.83	52.17
7	0	0.251	0.242	0.493	0	50.91	49.09
8	0	0.245	0.199	0.444	0	55.12	44.88
9	0	0.212	0.210	0.422	0	50.24	49.76
10	0	0.255	0.231	0.486	0	52.47	47.53
Avg.	0	0.251	0.242	0.493	0	50.94	49.06

Gas production rate	=	16.69	l/d
Methane production rate	=	8.50	l/d
Specific methane production rate	=	15.68	ml CH ₄ /g MLVSS d
VFA Concentration	=	587	mg/l as acetic acid
Methane yield	=	4.93	ml CH ₄ /g COD removed
COD removal efficiency	=	12.02	%
MLVSS	=	23,457	mg/l
TSS	=	3,608	mg/l

Distillated sample 100 µl + Internal standard 100 µl

VFA	Concentration (ppm)
Ethanol	218
Acetic acid	88
Propionic acid	99
Butyric acid	67
Valeric acid	63

CURRICULUM VITAE

Name: Ms. Monnipa Wonganu

Date of Birth: December 13, 1983

Nationality: Thai

University Education:

2002–2006 Bachelor Degree of Industrial Chemistry, Faculty of Science,
Chiang Mai University, Chiang Mai, Thailand

Work Experience:

Jan-Dec 10 Position: Support and Technical Service
Company name: Merck Company Limited,
Bangkok, Thailand

Proceedings:

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