REFERENCES

Abbasi, T., Tauseef, S.M., and Abbasi, S.A. (2012) Anaerobic digestion for global warming control and energy generation: An overview. Renewable and Sustainable Energy Reviews, 16(5), 3228-3242.

Agriculture and Consumer Protection. "Renewable biological systems for alternative sustainable energy production" FAO Corporate Document Repository. [N/A]. 14 January 2014 <http://www.fao.org/docrep/w7241e/w7241e0f.htm#4.1.2>

Antonopoulou, G., Gavala, H.N., Skiadas, I.V., and Lyberatos, G. (2011) Effect of substrate concentration on fermentative hydrogen production from sweet sorghum extract. International Journal Hydrogen Energy, 36(8), 4843-4851.

Arooj, M.F., Han, S.K., Kim, D.H., and Shin, H.S. (2008) Effect of HRT on ASBR converting starch into biological hydrogen. International Journal of Hydrogen Energy, 33(22), 6509-6514.

Bica´kova, O. and Straka, P. (2012) Production of hydrogen from renewable resources and its effectiveness. International Journal of Hydrogen Energy, 37(16), 11563-11578.

Chandra, R., Takeuchi, H., and Hasegawa, T. (2012) Methane production from lignocellulosic agricultural crop waste: A review in content to second generation of biofuel production. Renewable and Sustainable Energy Reviews, 16(3), 1462-476.

Chatsiriwatana, S., Sreethawong, T., Somboonthanate, P., Rangsunvigit, P., and Chavadej, S. Hydrogen Production from Cassava Wastewater in Anaerobic Sequencing Batch Reactor: Effects of Cycle Time and COD: N Ratio. Burswood Entertainment Complex, Perth, Australia 27-30 September 2009. 25 May 2013 < http://www.icms.com.au/chemeca2009/abstract/181.asp >

Chen, W.H., Han, S.K., and Sung, S. (2003) Sodium inhibition of thermophilic methanogens. Journal of Environmental Methanogens, 129(6), 506-512.

Chen, W.H., Sung, S., and Chen, S.Y. (2009) Biological hydrogen production in an anaerobic sequencing batch reactor: pH and cyclic duration effects. International Journal of Hydrogen Energy, 34(1), 227-234.

Chong, M.L., Sabaratnam, V., Shirai Y., and Hassan, M.A. (2009) Biohydrogen production from biomass and industrial wastes by dark fermentation. International Journal of Hydrogen Energy, 34(8), 3277-3287.

da Silva, G.P., Mack, M., and Contiero, J. (2009) Glycerol: A promising and abundant carbon source for industrial microbiology. Biotechnology Advances, 27(1), 30-39.

Das, D. and Veziroglu, N.T. (2001) Hydrogen production by biological processes: a survey of literature. International Journal of Hydrogen Energy, 26(1), 13-28.

Drożdżyńska, A., Leja, K., and Czaczyk K. (2011) Biotechnology production of 1,3-propanediol from crude glycerol. BioTechnologia, 92(1), 92-100.

Eastan, A. D. and Gardner, L. E. (1983) Catalytic hydrodesulfurization or hydrodenitrogenation of organic compounds employing alumina, cobalt and molybdenum as the catalytic agent. United States Patent, Apr, 28, 1981

Encinar, J.M., González, J.F., and Rodríguez-Reinares, A. (2005) Biodiesel from used frying oil: Variables affecting the yields and characteristics of the biodiesel. Industrial Engineering Chemistry Research., 44(15), 5491-5499.

Fountoulakis, M.S. and Manios, T., (2009) Enhanced methane and hydrogen production from municipal solid waste and agro-industrial by-products co-digested with crude glycerol. Bioresource Technology, 100(12), 3043-3047.

Hallenbeck, P.C. and Benemann, T.N. (2002) Biological hydrogen production: fundamentals and limiting process. International Journal of Hydrogen Energy, 27(11-12), 1185-1193.

Hwang, J., Choi, J., Abou-Shanab, Bhatnagar, A., Min, B., Song, H., Kumar, E., Choi, J., Lee, E., Kim, Y., Um, S., Lee, D., and Jeon B. (2009) Effect of pH and sulfate concentration on hydrogen production using anaerobic mixed microflora. International Journal of Hydrogen Energy, 34(24), 9702-9710.

Intanoo, P., Rangsunvigit, P., Namprohm, W., Thamprajamchit, B., Chavadej, J., and Chavadej, S. (2012) Hydrogen production from alcohol wastewater by an anaerobic sequencing batch reactor under thermophilic operation: Nitrogen and phosphorous uptakes and transformation. International Hydrogen Energy, 37(15), 11104-11112.

Ito, T., Nakashimada, Y., Senba, K., Matsui, T., and Nishio, N. (2005) Hydrogen and ethanol production from glycerol-containing waste discharged after biodiesel manufacturing process. Journal of Bioscience and Bioengineering, 100(3), 260-265.

IEA Energy Technology Essentials. "Hydrogen Production & Distribution." OECD/IEA April 2007. 12 April 2013 <http://www.iea.org/techno/essentials5.pdf>

Kapdan, I.K. and Kargi, F. (2006) Bio-hydrogen production from waste materials. Enzyme and Microbial Technology, 38(5), 569-582.

Karadag, D. and Puhakka, J.A. (2008) Enhancement of anaerobic hydrogen production by iron and nickel. International Journal of Hydrogen Energy, 35(16), 8554-8560.

Kirtay E. (2011) Recent advances in production of hydrogen from biomass. Energy Conversion and Management, 52(4), 1778-1789.

Miller, G. Q. and Stoecker, J. "Selection of a hydrogen separation process." Conference proceeding. 1 January 1989. 20 April 2013 <http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=5276899>

Mittal, A. (2011) Biological wastewater treatment. (August, P 32-44). Water today

Mohan, S.V. (2009) Harnessing of biohydrogen from wastewater treatment using mixed fermentative consortia: Process evaluation towards optimization. International Journal of Hydrogen Energy, 34(17), 7460-7474.

O-Thong,S., Prasertsan, P., Karakasheu, D., and Angelidaki, I. (2008) Thermophilic fermentation hydrogen production by the newly isolated thermoanaerobacterium. International Journal of Hydrogen Energy, 33(4), 1204-1214.

O-Thong, S., Prasertsan, P., Intrasungkha, N., Dhamwichukorn, S., and Birkeland N. (2008) Opimization of simultaneous thermophilic fermentative hydrogen production and COD reduction from palm oil mill effluent by Thermoanaerobacterium-rich sludge. International Journal of Hydrogen Energy, 33(4), 1221-1231.

Richard L. Bain. (2010) Hydrogen Production from Biomass. U.S.A.: National Renewable Energy Laboratory of the U.S.

Rinzema, A., Lier, J.,v., and Lettinga, G. (1998) Sodium inhibition of acetoclastic methanogens in granular sludge from a UASB reactor Enzyme and Microbial Technology, 10(1), 24-32.

Serna E. "Anaerobic digestion process." Waste-to-Energy Research and Technology Council. 25 November 2009. 24 January 2014 < http://www.wtert.eu/default.asp?Menue=13&ShowDok=12>

Sarma, S.J., Brar, S.K., Sydney, E.B., Bihan, Y.L., Buelna, G., and Soccol, C.R. (2012) Microbial hydrogen production by bioconversion of crude glycerol International Journal of Hydrogen Energy, 37(8), 6473-6490.

Sharma, Y. and Li, B. (2009) Optimizing hydrogen production from organic wastewater treatment in batch reactors through experimental and kinetic analysis. International Journal of Hydrogen Energy, 34(15), 6171-6180.

Shirasaki, Y., Tsuneki, T., Ota, Y., Yasuda, I., Tachibana, S., Nakajima, H., and Kobayashi, K. (2009) Development of membrane reformer system for highly efficient hydrogen production from natural gas. International Journal of Hydrogen Energy, 34(10), 4482-4487.

Sile López, J.Á., Ángeles Martín Santos, M., Chica Pérez, A.F., and Martín, A. M. (2009) Anaerobic digestion of glycerol derived from biodiesel manufacturing. Bioresource Technology, 100(23), 5609-5615.

Sittijunda, S. and Reungsang, A. (2012) Media optimization for biohydrogen production from waste glycerol by anaerobic thermophilic mixed cultures. International Journal of Hydrogen Energy, 37(20), 15473-15482.

Sittijunda, S. and Reungsang, A. (2012) Biohydrogen production from waste glycerol and sludge by anaerobic mixed cultures. International Journal of Hydrogen Energy, 37(18), 13789-13796

Sreethawong, T., Chatsiriwatana, S., Rangsunvigit,P., and Chavadej, S. (2010) Hydrogen production from cassava wastewater using an anaerobic sequencing batch reactor: Effect of operational parameter, COD:N ratio, and organic acid composition. International Journal of Hydrogen Energy, 35(9), 4092-4102.

Ueno, Y., Otsuka, S., and Morimoto, M. (1996) Hydrogen production from industrial wastewater by anaerobic microflora in chemostat culture. Journal of Fermentation and Bioengineering, 82(2), 194-197

Wang, J. and Wan, W. (2009) Factor influencing fermentative hydrogen production International Journal of Hydrogen Energy, 34(2), 799-811.

Wang, J. and Wan, W. (2008) Influence of Ni^{2+} concentration on biohydrogen production. Biosource Technology, 99(18), 8864-8868.

Wei, J., Liu, Z.-T., and Zhang, X. (2010) Biohydrogen production from starch wastewater and application in fuel cell. International Journal of Hydrogen Energy, 35(7), 2949-2952.

Wikipedia "Anaerobic digestion." Free encyclopedia. 22 May 2013. 26 May 2013 <http://en.wikipedia.org/wiki/Anaerobic_digestion>

Yu, H., Zhu, Z. Hu, W., and Zhang, H. (2002) Hydrogen production from rice winery wastewater in an upflow anaerobic reactor by using mixed anaerobic cultures. International Journal of Hydrogen Energy, 27(11-12), 1359-1365.

Yuwa-amornpitak, T. (2012) Bio-hydrogen production from bioglycerol waste from used oil by bacterium isolated from wastewater sludge. Journal of Environmental Science and Technology, 5(5), 373-380.

Zeng, A. P. (1996) Pathway and kinetic analysis of 1,3-propanediol production from glycerol fermentation by Clostridium butyricum. Bioprocess Engineering, 14(4), 169-175.

Zhang, H., Lin, G., and Chen, J. (2010) Evaluation and calculation on the efficiency of a water electrolysis system for hydrogen production. International Journal of Hydrogen Energy, 35(20), 10851-10858.

Zhang, T., Liu, H., and Fang, H.H.P. (2003) Biohydrogen production from starch in wastewater under thermophilic condition. International Journal of Environmental Management, 69(2), 149-156.

APPENDICES

Appendix A Gas Chromatograph's Calibration Curves

Table A1 Gas chromatograph's calibration curves for hydrogen (H_2)

Volume of Hydrogen (ml)	Peak Area
0.02	1101005
0.04	2016179
0.08	3680042
0.1	5675328
0.2	11471761
0.4	22832569

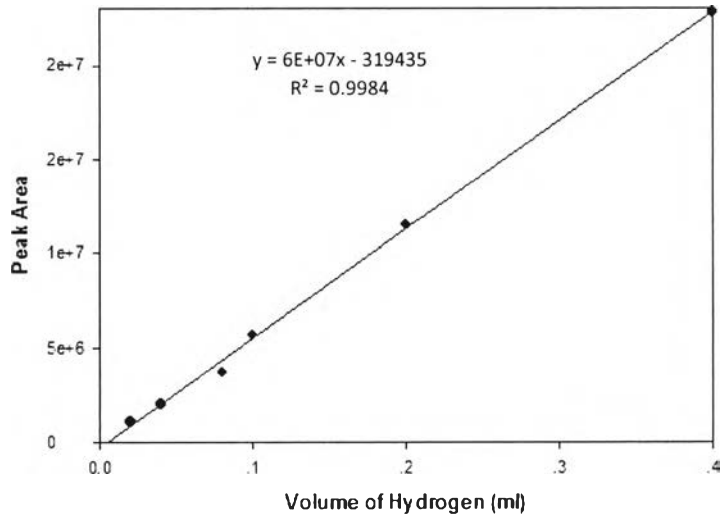

Figure A1 The relationship between amount of hydrogen (H_2) and peak area.

Equation $$\text{Amount of hydrogen} = \frac{\text{Peak area} + 319435}{6 \times 10^7}$$

Table A2 Gas chromatograph's calibration curves for nitrogen (N_2)

Volume of Nitrogen (ml)	Peak Area
0.02	69431
0.04	188161
0.08	426068
0.1	478146
0.2	1008515
0.4	2155800
0.6	3309337

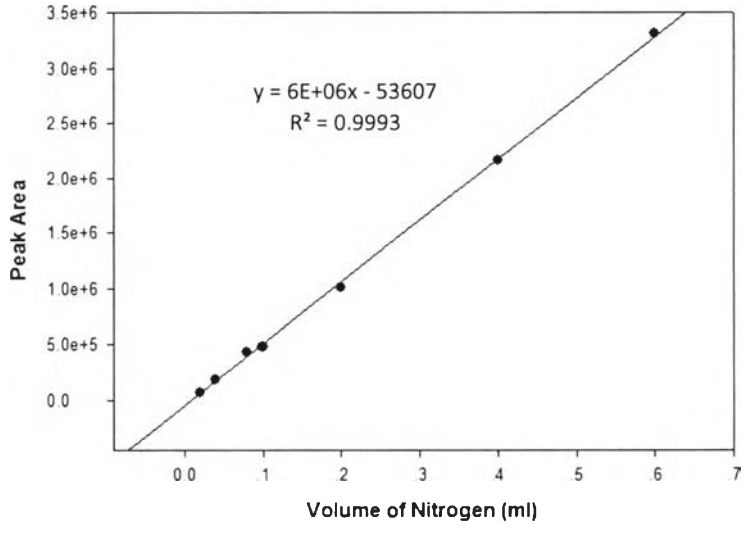

Figure A2 The relationship between amount of nitrogen (N_2) and peak area.

Equation

$$\text{Amount of nitrogen} = \frac{\text{Peak area} + 53607}{6 \times 10^6}$$

Table A3 Gas chromatograph's calibration curves for oxygen (O_2)

Volume of Oxygen (ml)	Peak Area
0.02	81122
0.04	233918
0.08	514527
0.1	662766
0.2	1366208
0.4	2738126

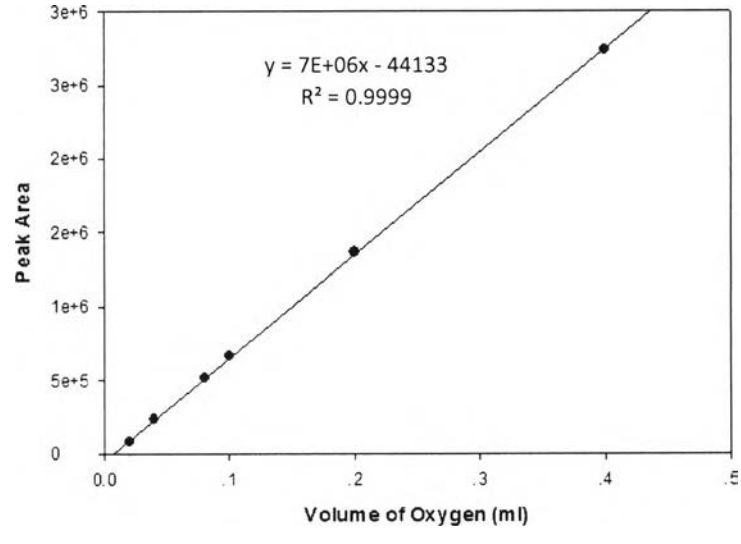

Figure A3 The relationship between amount of oxygen (O_2) and peak area.

Equation $$\text{Amount of oxygen} = \frac{\text{Peak area} + 44133}{7 \times 10^6}$$

Table A4 Gas chromatograph's calibration curves for methane (CH_4)

Volume of Methane (ml)	Peak Area
0.02	151094
0.04	523919
0.08	998851
0.1	1366651
0.2	2898103
0.4	5880444

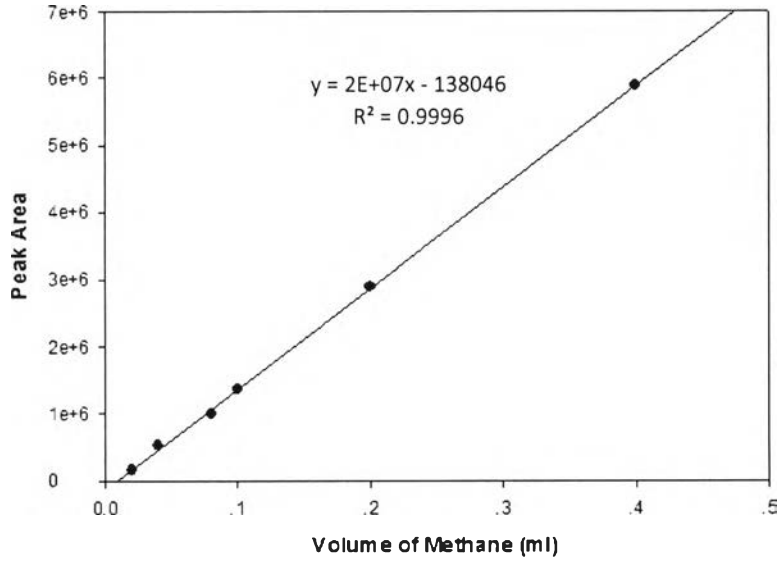

Figure A4 The relationship between amount of methane (CH_4) and peak area.

Equation $$\text{Amount of methane} = \frac{\text{Peak area} + 138046}{2 \times 10^7}$$

Table A5 Gas chromatograph's calibration curves for carbon dioxide (CO_2)

Volume of Carbon Dioxide (ml)	Peak Area
0.02	4238
0.04	188166
0.08	293029
0.1	354304
0.2	747872
0.4	1515064

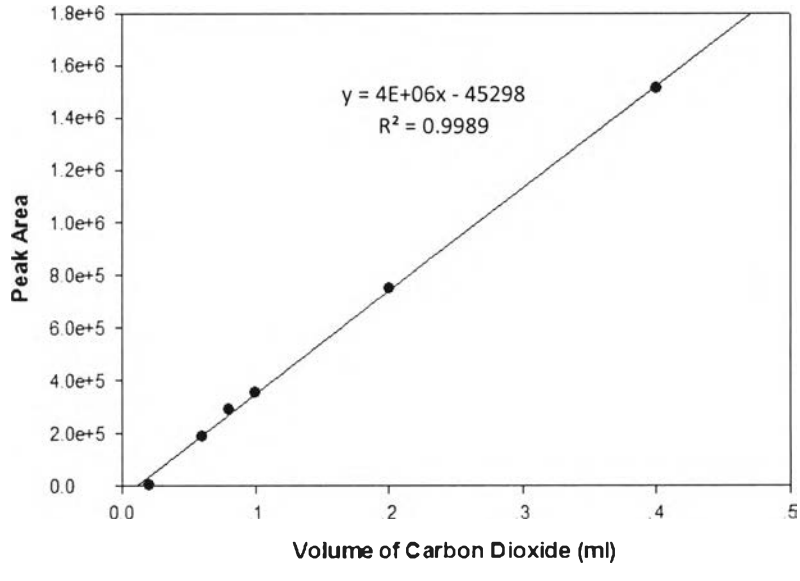

Figure A5 The relationship between amount of carbon dioxide (CO_2) and peak area.

Equation $$\text{Amount of carbon dioxide} = \frac{\text{Peak area} + 45298}{4 \times 10^6}$$

Appendix B High Performance Liquid Chromatograph's Calibration Curves

Table B1 High performance liquid chromatograph's calibration curves for acetic acid (CH_3COOH)

Concentration of Acetic Acid (ppm)	Peak Area
1000	1046431
2000	1200121
3000	1339396
4000	1483875
5000	1714556

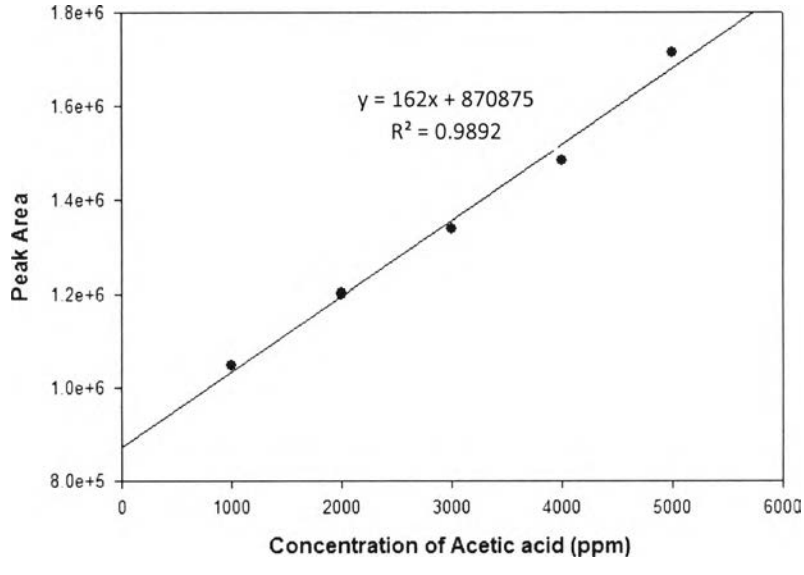

Figure B1 The relationship between concentration of acetic acid (CH_3COOH) and peak area.

Equation $$\text{Concentration of acetic acid} = \frac{\text{Peak area} - 870875}{162}$$

Table B2 High performance liquid chromatograph's calibration curves for propionic acid (CH_3CH_2COOH)

Concentration of Propionic Acid (ppm)	Peak Area
1000	489918
2000	734981
3000	960145
4000	1307054
5000	1600112

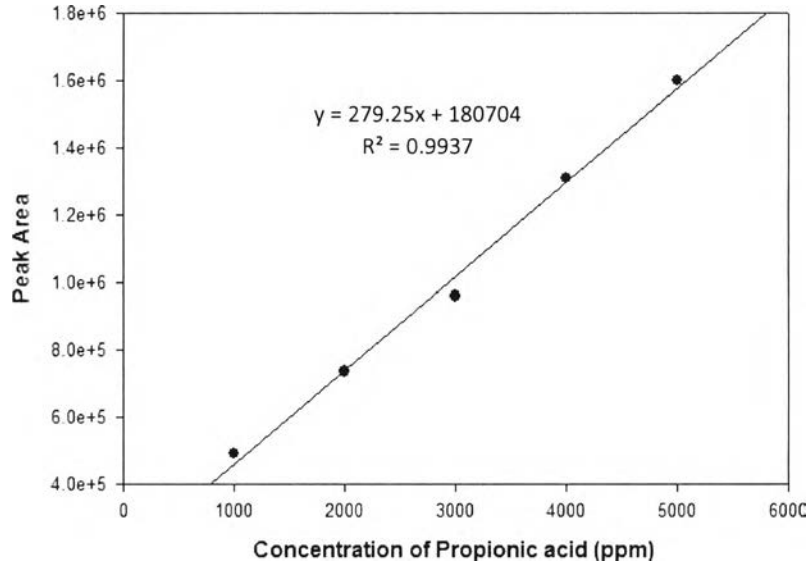

Figure B2 The relationship between concentration of propionic acid (CH_3CH_2COOH) and peak area.

Equation $$\text{Concentration of propionic acid} = \frac{\text{Peak area} - 180704}{279.25}$$

Table B3 High performance liquid chromatograph's calibration curves for butyric acid ($CH_3CH_2CH_2COOH$)

Concentration of Butyric Acid (ppm)	Peak Area
1000	12456
2000	498555
3000	1117245
4000	1668629
5000	2343480

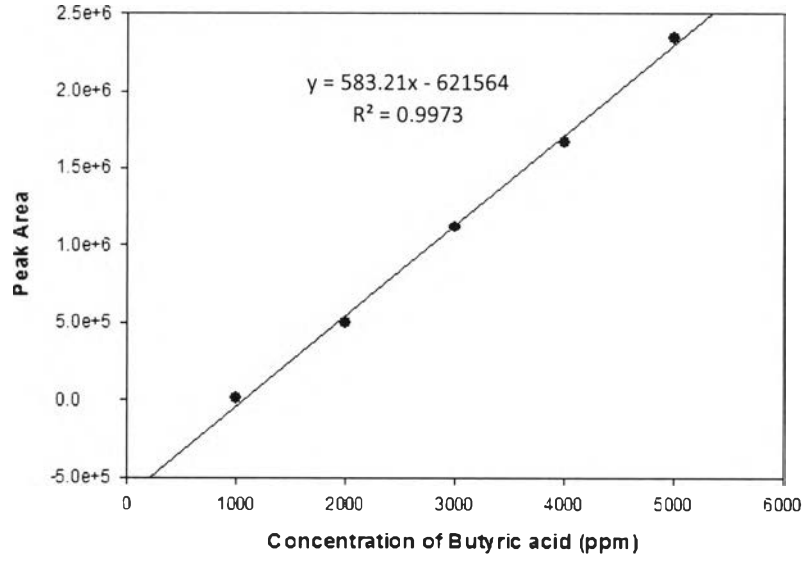

Figure B3 The relationship between concentration of butyric acid ($CH_3CH_2CH_2COOH$) and peak area.

Equation $$\text{Concentration of butyric acid} = \frac{\text{Peak area} + 621564}{583.21}$$

Table B4 High performance liquid chromatograph's calibration curves for valeric acid ($CH_3CH_2CH_2CH_2COOH$)

Concentration of Valeric Acid (ppm)	Peak Area
1000	12456
2000	498555
3000	1117245
4000	1668629
5000	2343480

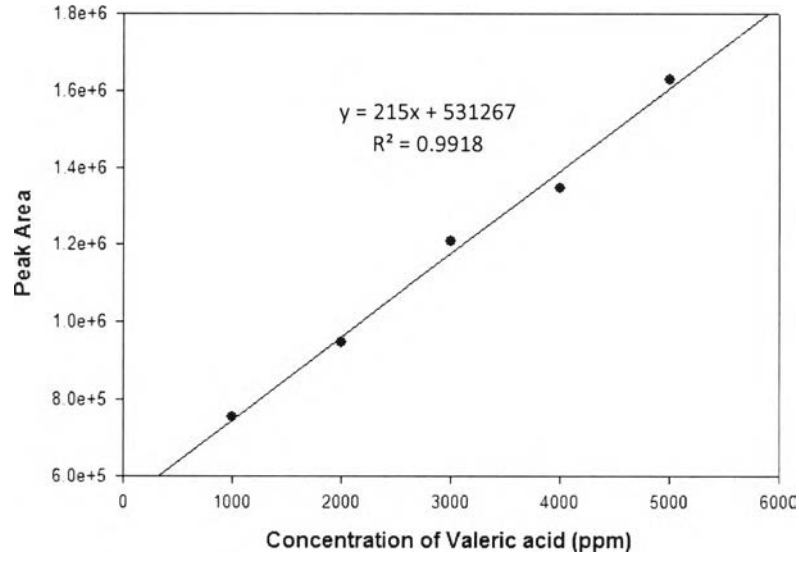

Figure B4 The relationship between concentration of valeric acid ($CH_3CH_2CH_2CH_2COOH$) and peak area.

Equation $$\text{Concentration of valeric acid} = \frac{\text{Peak area} - 531267}{215}$$

Table B5 High performance liquid chromatograph's calibration curves for glycerine ($C_3H_8O_3$)

Concentration of Glycerine (ppm)	Peak Area
1000	1431858
2000	1730003
3000	2441090
4000	3212975
5000	4164848

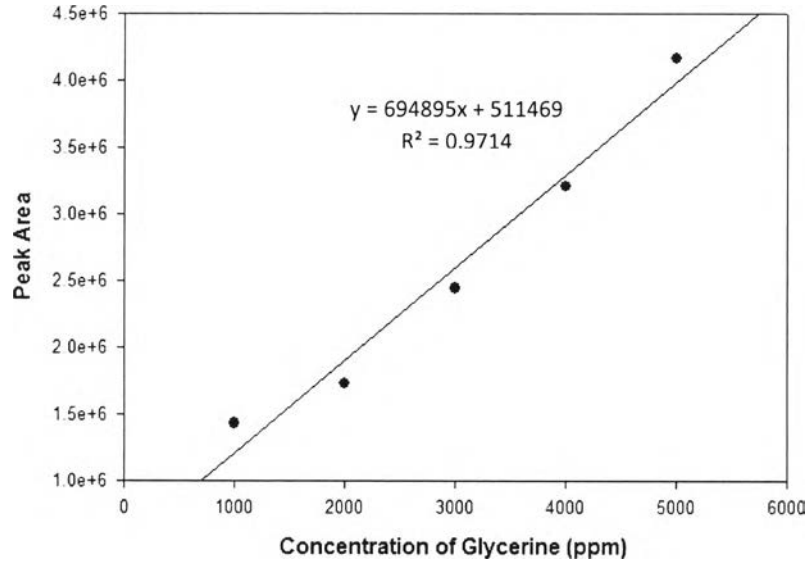

Figure B5 The relationship between concentration of glycerine ($C_3H_8O_3$) and peak area.

Equation $$\text{Concentration of glycerine} = \frac{\text{Peak area} - 511469}{694895}$$

Table B6 High performance liquid chromatograph's calibration curves for 1,3-propanediol ($C_3H_8O_2$)

Concentration of 1,3-Propanediol (ppm)	Peak Area
1000	13475
2000	49243
3000	69923
4000	89568
5000	123472

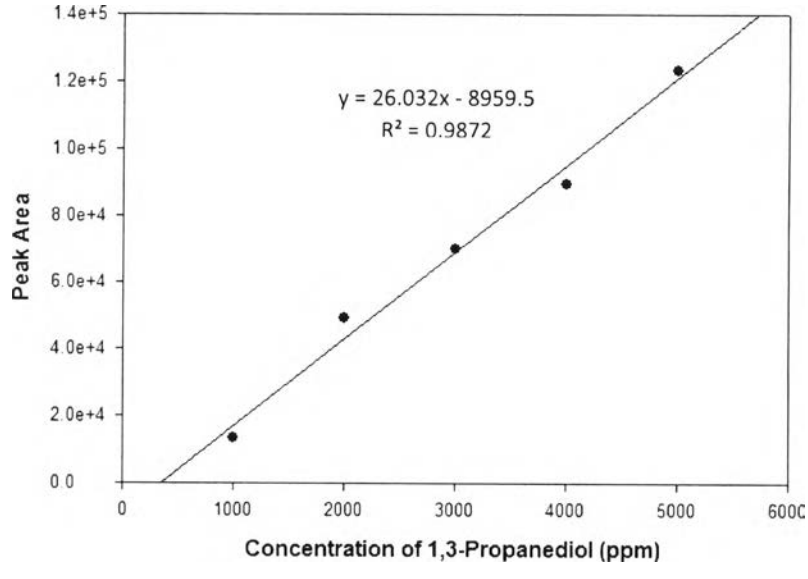

Figure B6 The relationship between concentration of 1,3-propanediol ($C_3H_8O_2$) and peak area.

Equation $$\text{Concentration of } 1,3-\text{propanediol} = \frac{\text{Peak area} + 8959.5}{26.032}$$

Table B7 High performance liquid chromatograph's calibration curves for ethanol (C_2H_6O)

Concentration of Ethanol (ppm)	Peak Area
1000	243063
2000	652330
3000	1009809
4000	1252490
5000	1819504

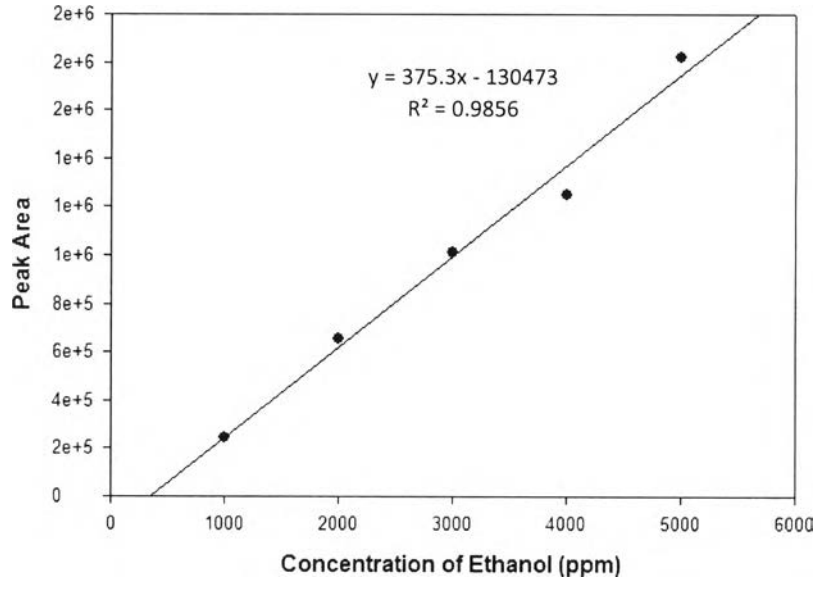

Figure B7 The relationship between concentration of ethanol (C_2H_6O) and peak area.

Equation $$\text{Concentration of ethanol} = \frac{\text{Peak area} + 130473}{375.3}$$

Appendix C Preparation of 5 wt./vol.% NaOH Solution for pH Control System

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

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

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

D 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

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

$$= 17.78 \text{ M}$$

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

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

$$= 0.0333 \text{ M}$$

Dilution of acetic acid

$N_1V_1 = N_2V_2$

$V_1 = N_2V_2/N_1$

$= (0.0333 \text{x} 1)/17.78$

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

D 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

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

$$= 4.04 \text{ g}$$

D 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	

CURRICULUM VITAE

Name : Miss Pranee Tangkathitipong

Date of Birth : July 23, 1989

Nationality : Thai

University Education :

2008-2011 Bachelor Degree of Chemical Engineering, Faculty of Engineering, Mahidol University, Nakorn Pathom, Thailand

Working Experience:

2010 Position: Internship Student
Company name: Thai Lube Base CO., LTD.
Chonburi, Thailand

Proceedings:

1. Tangkathitipong, P.; Intanoo, P.; Chavadej, S., (2014, April 22) Hydrogen and Methane Production from Biodiesel Wastewater by Two-stage Anaerobic Sequencing Batch Reactor (ASBR) under Mesophilic Temperature. Proceedings of The 5nd National Research Symposium on Petroleum, Petrochemicals, and Advanced Materials and The 20th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand