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APPENDICES

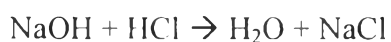
Appendix A Titration Method

1. Standardization of NaOH was measured by using potassium acid phthalate (Equation 1)

$$\text{Normality} = (W_p * 1000) / (MW * (V - V_b)) \quad (1)$$

Where W_p = Weight of potassium acid phthalate (g)
 V = Amount of NaOH was used in titration sample (ml)
 V_b = Amount of NaOH was used in titration blank (ml)
MW = Molecular weight of potassium acid phthalate

2. A 0.02 M of NaOH solution was used to measure the concentration of HCl solution.



To evaluate the acidity of catalysts was calculated as follows (Equation 2)

$$c(\text{H}^+) = \frac{c(\text{OH}^-) \times \Delta V}{m} \quad (2)$$

Where $c(\text{H}^+)$ = the acid quantity of sulfonated samples
 $c(\text{OH}^-)$ = the concentration of the NaOH solution
 ΔV = the volume of the NaOH solution consumed in titration
M = the quality of the catalyst samples in ultrasonic oscillation reaction

Table A.1 Calculation the acid site of catalysts

| Sample | No. | Volume (ml) | | Weight of Catalyst (g) | NaOH (ml) | Total Acid site (mmol/g) | Avg. |
|-----------------------------------|-----|-------------|-------|------------------------|-----------|--------------------------|------|
| | | Start | Final | | | | |
| Catalyst sulfonated of 110 °C 5 h | 1 | 0.00 | 3.55 | 0.0514 | 3.55 | 1.38 | 1.36 |
| | 2 | 0.00 | 3.65 | 0.0550 | 3.65 | 1.33 | |
| | 3 | 0.00 | 3.50 | 0.0512 | 3.50 | 1.37 | |
| Catalyst sulfonated of 130 °C 5 h | 1 | 0.00 | 3.00 | 0.0549 | 3.00 | 1.09 | 1.12 |
| | 2 | 0.00 | 2.85 | 0.0497 | 2.85 | 1.15 | |
| Catalyst sulfonated of 150 °C 5 h | 1 | 0.00 | 2.95 | 0.0504 | 2.95 | 1.17 | 1.17 |
| | 2 | 0.00 | 3.15 | 0.0527 | 3.15 | 1.20 | |
| | 3 | 0.00 | 2.95 | 0.0514 | 2.95 | 1.15 | |
| Catalyst sulfonated of 110 °C 3 h | 1 | 0.00 | 3.00 | 0.0495 | 3.00 | 1.21 | 1.19 |
| | 2 | 0.00 | 3.15 | 0.0531 | 3.15 | 1.19 | |
| | 3 | 0.00 | 3.20 | 0.0551 | 3.20 | 1.16 | |
| Catalyst sulfonated of 110 °C 7 h | 1 | 0.00 | 2.80 | 0.0515 | 2.80 | 1.09 | 1.13 |
| | 2 | 0.00 | 2.85 | 0.0493 | 2.85 | 1.16 | |
| | 3 | 0.00 | 2.90 | 0.0511 | 2.90 | 1.14 | |

Appendix B Gas Chromatography (GC)

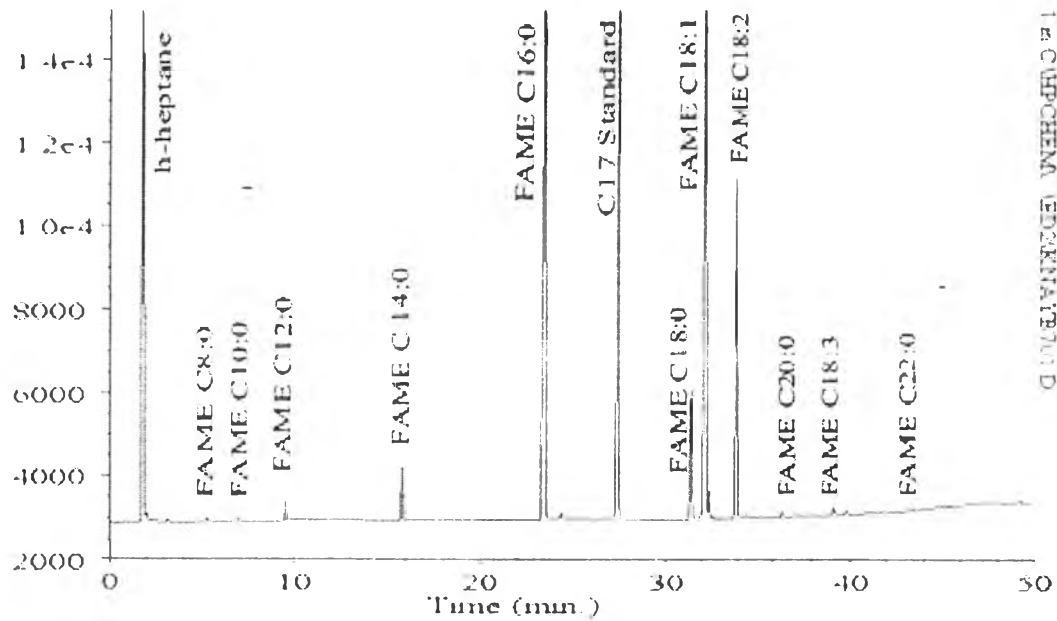


Figure B.1 Chromatogram of fatty acid methyl ester (FAMES) in biodiesel.

The methyl ester content, yield, and conversion were determined using Equation (3).

$$C = \frac{(\sum A) - A_{EI}}{A_{EI}} \times \frac{C_{EI} \times V_{EI}}{m} \times 100 \quad (3)$$

| | |
|----------|---|
| C | Methyl ester content or Fatty acid methyl ester (FAME) |
| $\sum A$ | The overall area of methyl ester from C_{14} to C_{24} |
| A_{EI} | The peak area of that which is aligned with methylheptadecanoate solution |
| C_{EI} | Concentration in mg/ml of methyl heptadecanoate solution |
| V_{EI} | Volume of methyl heptadecanoate solution |
| m | Weight in mg of sample |

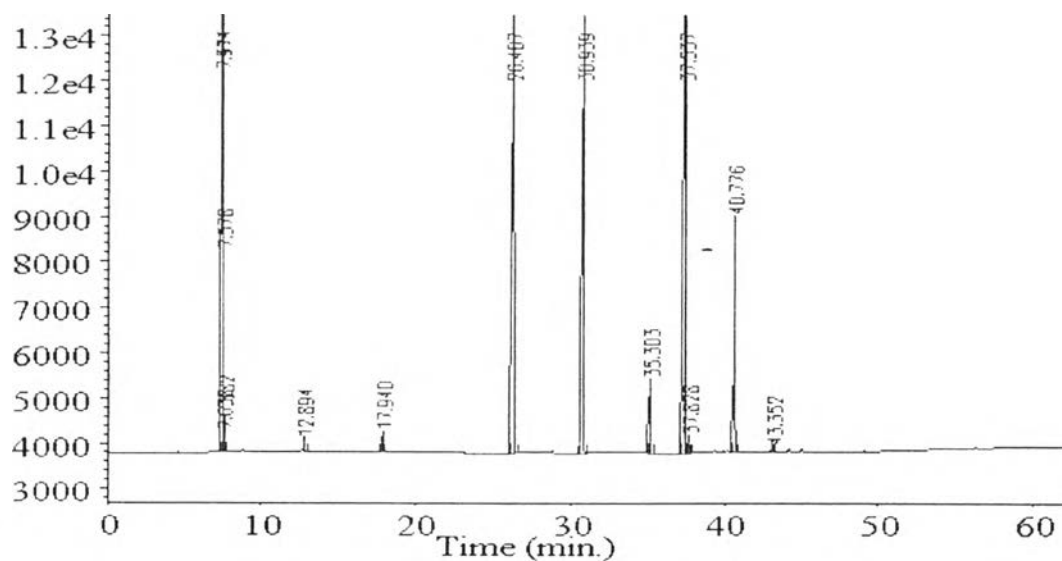


Figure B.2 Methyl ester content of biodiesel from catalyst sulfonated of 110 °C 5 h

Table B.2 The methyl ester contents data of biodiesel from catalyst sulfonated of 110 °C 5 h analyzed by using a Hewlett Packard GC model 5890

| Peak | Ret Time | Type | Width | Area | Start Time | End Time |
|------|----------|------|-------|---------|------------|----------|
| 1 | 7.823 | BH | 0.024 | 6951003 | 7.757 | 7.87 |
| 2 | 7.888 | HB | 0.03 | 54205 | 7.87 | 8.147 |
| 3 | 7.998 | BB | 0.034 | 3483 | 7.958 | 8.05 |
| 4 | 18.645 | BB | 0.092 | 2576 | 18.517 | 18.9 |
| 5 | 19.427 | BB | 0.084 | 883 | 19.327 | 19.577 |
| 6 | 27.123 | BB | 0.117 | 24789 | 26.937 | 27.603 |
| 7 | 29.371 | BB | 0.114 | 2303 | 29.217 | 29.617 |
| 8 | 29.811 | BV | 0.124 | 15770 | 29.653 | 30.17 |
| 9 | 30.294 | MM | 0.179 | 1148 | 30.183 | 30.582 |
| 10 | 31.721 | BB | 0.121 | 98439 | 31.433 | 32.36 |
| 11 | 34.091 | BB | 0.101 | 2076 | 33.92 | 34.333 |

Table B.2 (cont.) The methyl ester contents data of biodiesel from catalyst sulfonated of 110 °C 5 h analyzed by using a Hewlett Packard GC model 5890

| Peak | Ret Time | Type | Width | Area | Start Time | End Time |
|------|----------|------|-------|--------|------------|----------|
| 12 | 36.051 | BB | 0.112 | 6251 | 35.853 | 36.37 |
| 13 | 37.534 | -BV | 0.157 | 4478 | 37.27 | 37.66 |
| 14 | 37.757 | VV | 0.145 | 4096 | 37.66 | 37.96 |
| 15 | 38.386 | VV | 0.136 | 283447 | 37.96 | 38.541 |
| 16 | 38.621 | VB | 0.104 | 22255 | 38.541 | 39.07 |
| 17 | 39.191 | MM | 0.099 | 605 | 39.075 | 39.325 |
| 18 | 39.496 | MM | 0.131 | 898 | 39.325 | 39.775 |
| 19 | 40.233 | MM | 0.151 | 1118 | 39.881 | 40.464 |
| 20 | 40.807 | BV | 0.118 | 2001 | 40.607 | 41.013 |
| 21 | 41.14 | VB | 0.104 | 1550 | 41.013 | 41.357 |
| 22 | 41.551 | BV | 0.104 | 54838 | 41.357 | 42.027 |
| 23 | 44.063 | MM | 0.125 | 822 | 43.907 | 44.324 |
| 24 | 44.84 | MM | 0.152 | 706 | 44.529 | 45.041 |
| 25 | 45.204 | BB | 0.097 | 1852 | 45.047 | 45.417 |
| 26 | 45.996 | BB | 0.097 | 3621 | 45.863 | 46.293 |
| 27 | 48.966 | BB | 0.095 | 1488 | 48.817 | 49.177 |

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1. Namwong, K.; and Luengnaruemitchai, A. (2014, April 23) Biodiesel Production Using Solid Acid Catalyst via Esterification of Oleic Acid. Proceedings of the 5th Research Symposium on Petroleum, Petrochemical, and Advanced Materials and 20th PPC Symposium on Petroleum, Petrochemical, and Polymers, Bangkok, Thailand.
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