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APPENDICES

Appendix A Acid Titration Method

1. Standardization of KOH was measured by using potassium acid phatalate (titration grade)

$$\text{Normality} = (Wp*1000)/(\text{MW}*(V\text{-}Vb))$$

Where Wp = Weight of potassium acid phatalate (g)

V = Amount of KOH was used in titration sample (ml)

Vb = Amount of KOH was used in titration blank (ml)

MW = Molecular weight of potassium acid phatalate

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

$$KOH + HCl \rightarrow H_2O + KCl$$

3. To evaluate the basicity of catalysts, the remained HCl in the solution was calculated.

Table A.1 Calculation the basic site of catalysts

Sample	No.	Volume (ml)		KOH (ml)	HCl (ml)	Weight of Catalyst	Back Titration	Total Basic Site (mmol)	Total Basic Site (mmol/g)	Avg.
		Start	Final							
CP (Ca:Zn = 1:3, 800 °C)	1	10	13.95	3.95	5	0.1005	2.25	0.0476	0.473	0.475
	2	10	13.9	3.9	5	0.102	2.3	0.0486	0.476	
CP (Ca:Zn = 1:3, 800 °C)	1	13	13.55	0.55	5	0.1008	5.65	0.1195	1.185	1.192
	2	14	14.45	0.45	5	0.1015	5.75	0.1216	1.198	

Appendix B Gas Chromatography (GC)

Table B.1 Calculation of the methyl ester yield and weight of palm oil

Free Fatty Acid	Molecular	Molecular weight (X1)	Methyl ester (wt%) (X2)	(X1 x X2)
caprylic (C8:0)	$C_{27}H_{50}O_2$	470	0.01	0.05
carpic (C10:0)	$C_{33}H_{62}O_2$	554	0.01	0.06
Lauric (C12:0)	$C_{39}H_{74}O_2$	638	0.20	1.28
Myristic (C14:0)	$C_{45}H_{86}O_2$	722	0.83	5.99
Palmitic (C16:0)	$C_{51}H_{98}O_2$	806	40.29	324.74
Stearic (C18:0)	$C_{57}H_{96}O_2$	890	3.70	32.93
Oleic (C18:1)	$C_{57}H_{94}O_2$	884	43.73	386.57
Linoleic (C18:2)	$C_{57}H_{92}O_2$	878	10.64	93.42
Linolenic (C18:3)	$C_{57}H_{90}O_2$	872	0.19	1.66
Arachidic (C20:0)	$C_{63}H_{122}O_2$	974	0.30	2.92
Total			100	849.61

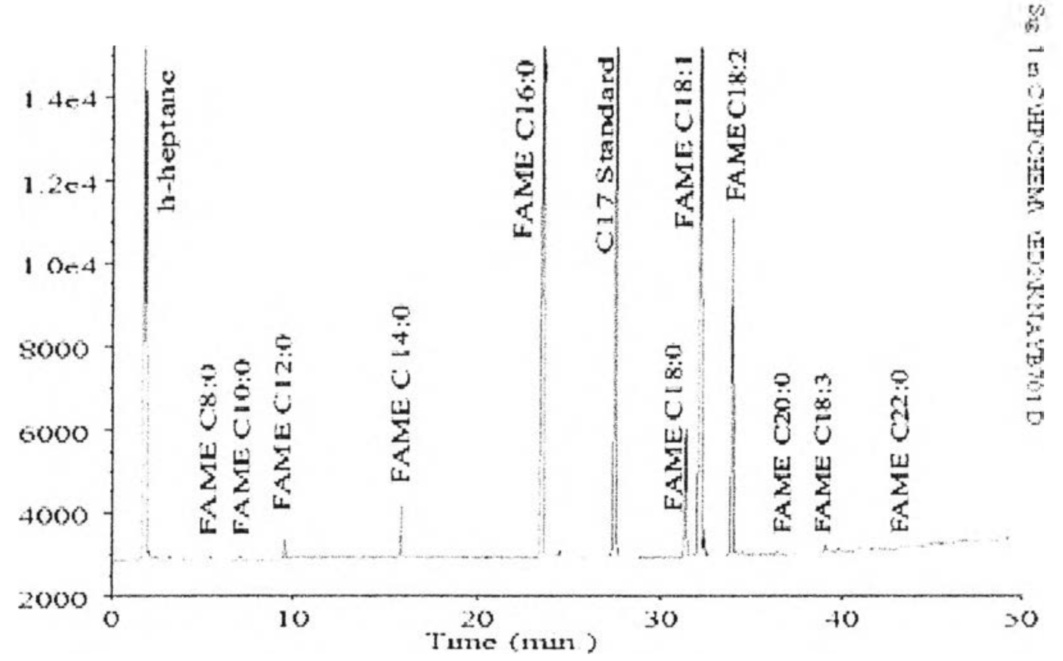

Figure B.1 Chromatogram of fatty acid methyl ester (FAMEs) in biodiesel

The methyl ester content, yield, and conversion were determined using Equations (1).

$$C = \frac{\left(\sum A\right) - A_{EI}}{A_{EI}} \times \frac{C_{EI} \times V_{EI}}{m} \times 100 \qquad (1)$$

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

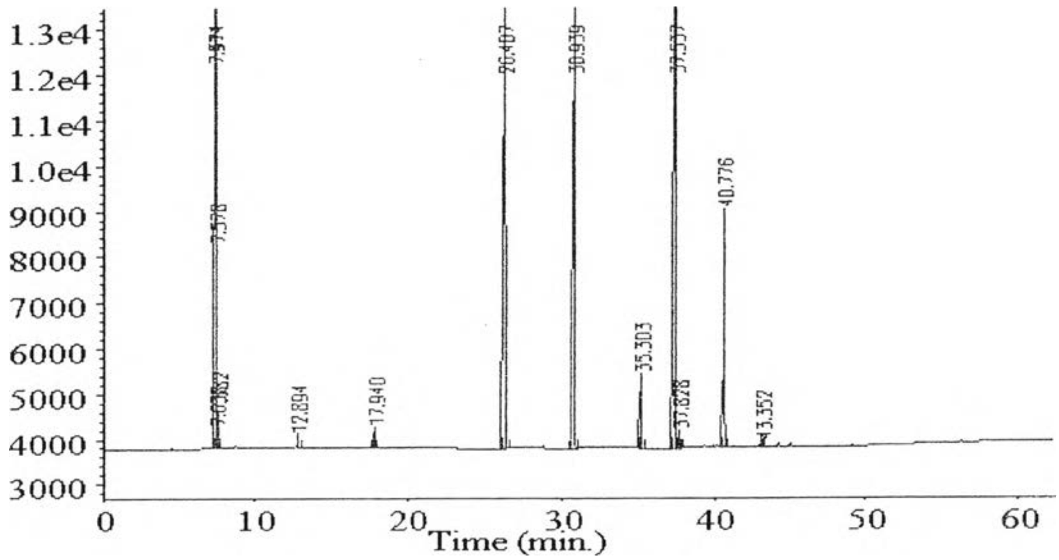

Figure B.2 Methyl ester content of biodiesel from CaO–ZnO (1:3:CP:calcined 800 °C:8h) catalyst

Table B.2 The methyl ester contents data of biodiesel from CaO–ZnO (1:3:CP:calcined 800 °C:8h) catalyst analyzed by using a Hewlett Packard GC model 5890

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.471	BHS	0.029	2406578	7.393	7.492
2	7.514	HHS	0.023	3785538	7.492	7.561
3	7.578	HBS	0.027	8031	7.561	7.773
4	7.638	BVT	0.029	611	7.611	7.655
5	7.682	VBT	0.032	1519	7.655	7.723
6	12.894	BB	0.062	1309	12.793	13
7	17.94	BB	0.082	2766	17.79	18.08
8	26.407	BB	0.091	97378	26.147	26.647
9	30.939	BB	0.084	62559	30.717	31.167
10	35.303	BB	0.081	9578	35.15	35.467
11	37.537	BV	0.086	105979	37.287	37.717
12	37.828	VB	0.073	1992	37.717	37.957
13	40.776	BB	0.071	27369	40.62	40.983
14	43.352	BB	0.076	845	43.247	43.477

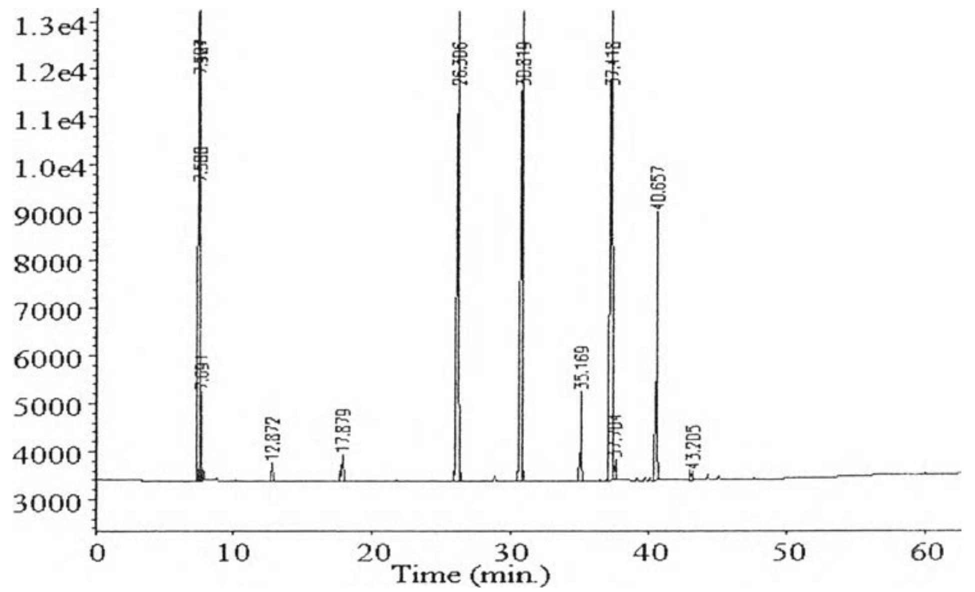

Figure B.3 Methyl ester content of biodiesel from CaO–ZnO (1:3:IWI:calcined 900 °C:8h) catalyst

Table B.3 The methyl ester contents data of biodiesel from CaO–ZnO (1:3:IWI:calcined 900 °C:8h) catalyst analyzed by using a Hewlett Packard GC model 5890

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.487	BHS	0.027	2046039	7.41	7.502
2	7.524	HHS	0.024	4638069	7.502	7.572
3	7.588	HBS	0.032	12167	7.572	7.863
4	7.691	BVT	0.042	5236	7.621	7.74
5	12.872	BB	0.057	1469	12.77	12.973
6	17.879	BB	0.081	2971	17.747	18.03
7	26.306	BB	0.089	103317	26.05	26.55
8	30.819	BB	0.083	64452	30.593	31.017
9	35.169	BB	0.081	10285	35.013	35.36
10	37.418	BV	0.091	113620	37.17	37.577
11	37.704	VB	0.076	2185	37.577	37.833
12	40.657	BB	0.079	29566	40.45	40.813
13	43.205	BB	0.08	984	43.067	43.33

Appendix C Calculation of Crystal Size from X-ray Diffraction (XRD)

The Scherrer Equation

t, thickness = 0.89 $\lambda/(\beta \cos \theta)$

Sample	β (o)	β (radius)	Particle size (nm)
ZnO of CP (1:3, 800 °C)	0.251	0.004381	32.93
ZnO of CP (1:1, 800 °C)	0.237	0.004137	34.87

Example Crystal size of ZnO at CP (1:3, 800 °C)

β = 0.251 °, λ = 0.154 nm, 2θ = 36.365°

θ = 18.183 °; cos (18.183) = 0.950

360 ° = 2 x 3.142

β in radian = .297 x 2 x 3.142/(360) = .004381

t = 32.93 nm

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