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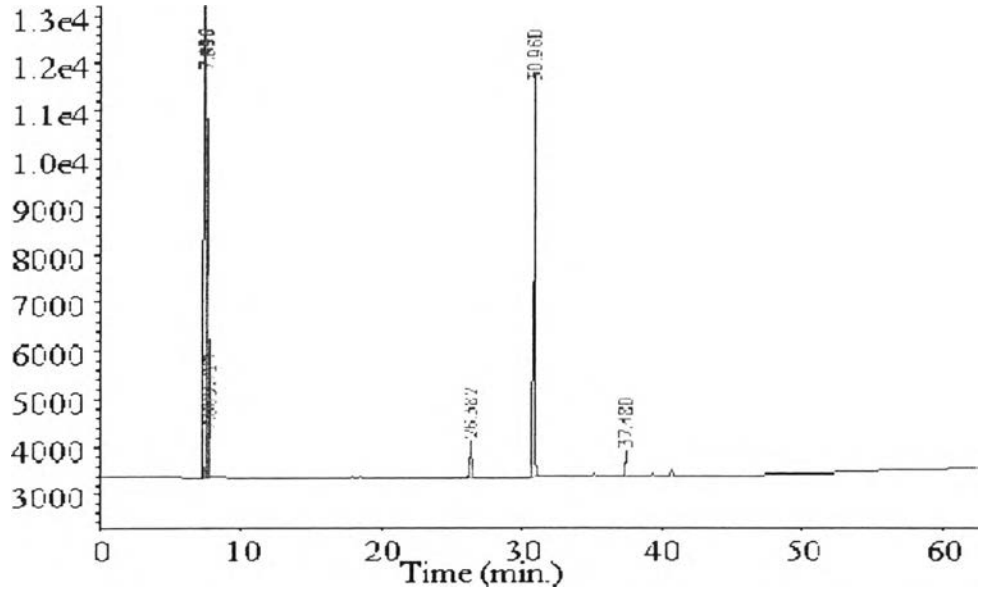
APPENDIX

Biodiesel Analysis

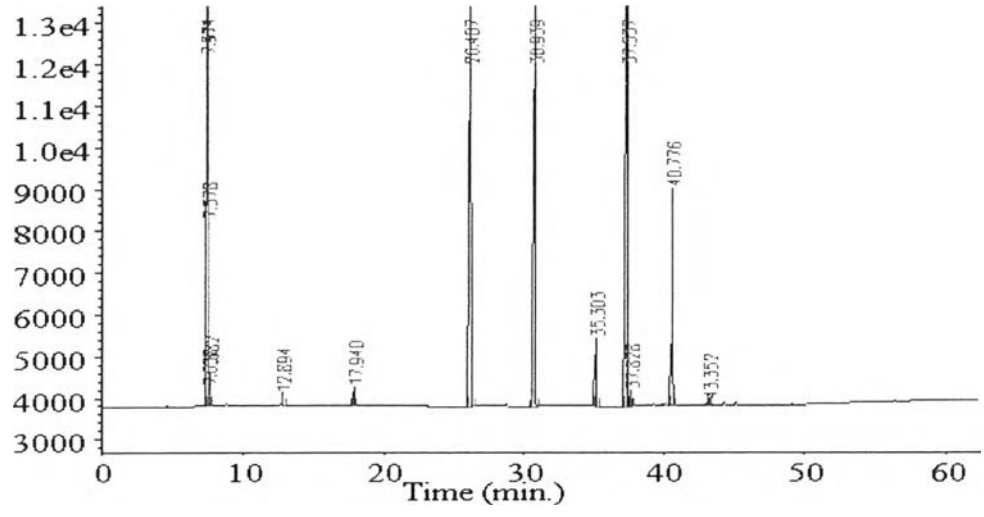
The methyl ester contents were analyzed by using a Hewlett Packard GC model 5890.

Gas Chromatograph (GC)



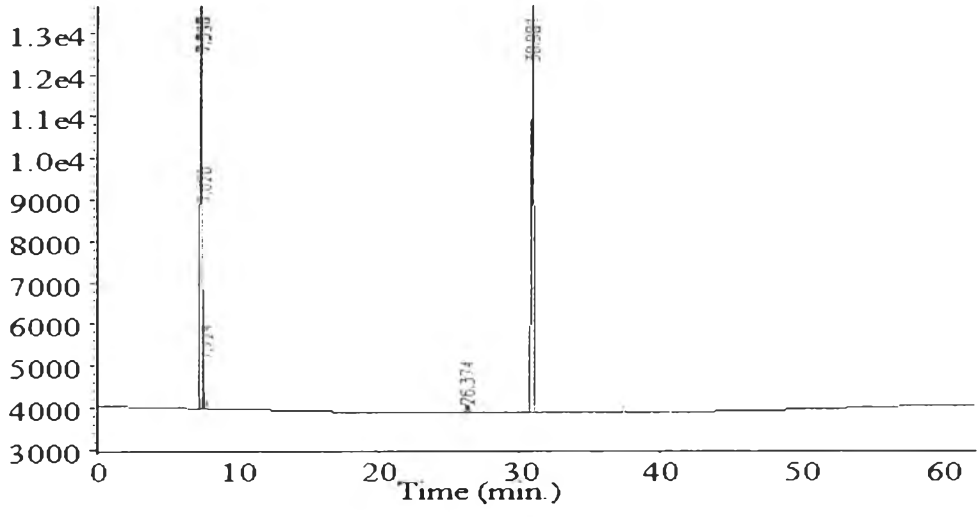
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.496	BHS	0.032	2487741	7.407	7.526
2	7.552	HHS	0.024	3831016	7.526	7.598
3	7.616	HBS	0.029	23954	7.598	7.813
4	7.665	BVT	0.021	339	7.651	7.69
5	7.721	VBT	0.031	2645	7.69	7.763
6	26.382	BB	0.08	4340	26.24	26.573
7	30.96	BB	0.082	48024	30.763	31.11
8	37.48	BB	0.071	2748	37.353	37.633

Figure A1 Methyl ester content of biodiesel from CaO–ZnO (1:3;CP:calcined 600 °C) catalyst.



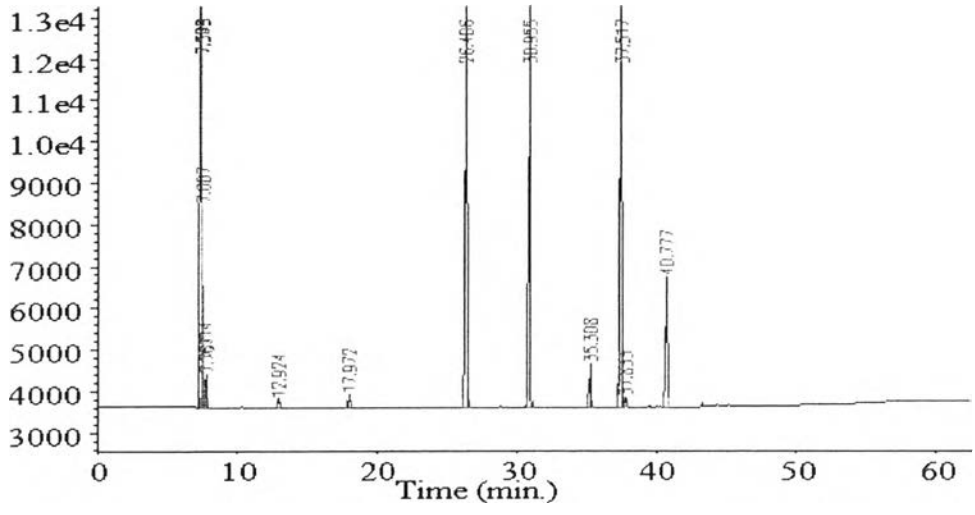
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.471	BHS	0.029	2406578	7.393	7.492
2	7.514	HHS	0.023	3785538	7.492	7.561
3	7.578	HBS	0.027	8031	7.561	7.773
4	7.638	BVT	0.029	611	7.611	7.655
5	7.682	VBT	0.032	1519	7.655	7.723
6	12.894	BB	0.062	1309	12.793	13
7	17.94	BB	0.082	2766	17.79	18.08
8	26.407	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 A2 Methyl ester content of biodiesel from CaO–ZnO (1:3:CP:calcined 800 °C:8h) catalyst.



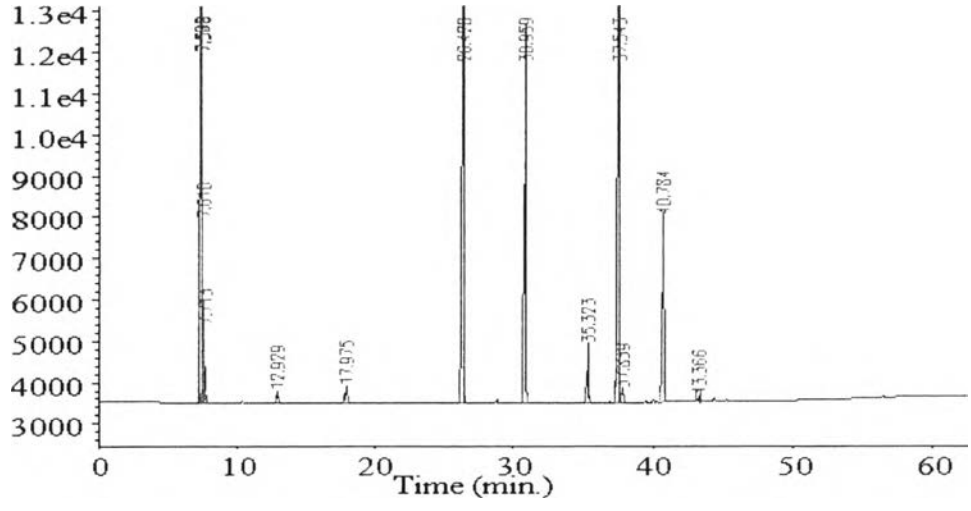
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.518	BHS	0.03	2820399	7.437	7.535
2	7.557	HHS	0.024	4388370	7.535	7.605
3	7.62	HBS	0.033	9680	7.605	7.817
4	7.724	BBT	0.044	3241	7.654	7.77
5	26.374	BB	0.078	971	26.233	26.51
6	30.981	BB	0.088	70386	30.723	31.19

Figure A3 Methyl ester content of biodiesel from CaO–ZnO (1:3;CP:calcined 900 °C) catalyst.



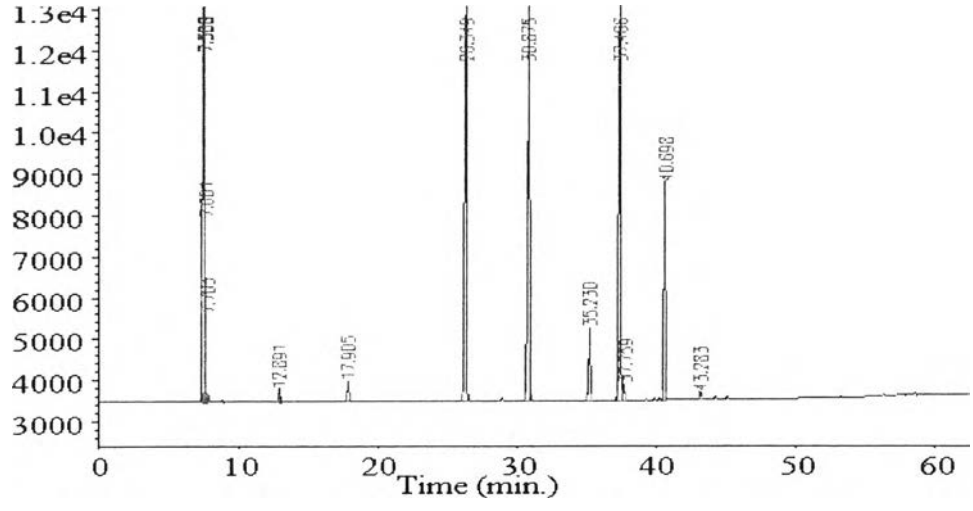
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.509	BHS	0.03	2335047	7.437	7.522
2	7.543	HHS	0.024	4309524	7.522	7.592
3	7.607	HBS	0.032	9381	7.592	7.93
4	7.714	BVT	0.048	3742	7.641	7.747
5	7.767	VVT	0.028	1422	7.747	7.807
6	12.924	BB	0.06	931	12.82	13.007
7	17.972	BB	0.085	1866	17.843	18.1
8	26.406	BB	0.085	62510	26.2	26.637
9	30.955	BB	0.084	60678	30.74	31.203
10	35.308	BB	0.08	5800	35.173	35.453
11	37.517	BB	0.078	63105	37.31	37.723
12	37.833	BB	0.064	1164	37.733	37.96
13	40.777	BB	0.081	16588	40.627	40.947

Figure A4 Methyl ester content of biodiesel from CaO–ZnO (1:3:CP:calcined 800 °C:2h) catalyst.



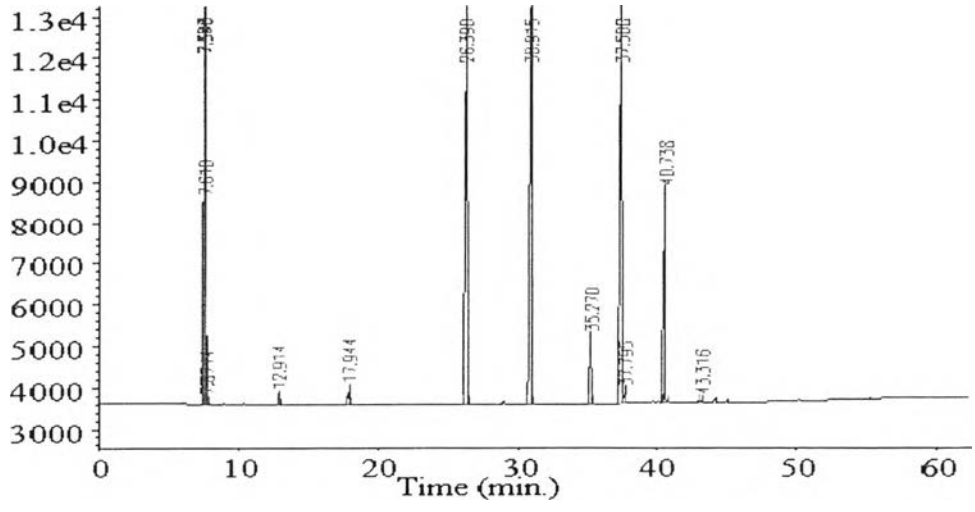
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.509	BHS	0.029	2382446	7.437	7.525
2	7.546	HHS	0.024	3861308	7.525	7.594
3	7.61	HBS	0.029	8773	7.594	7.813
4	7.713	BBT	0.046	5627	7.641	7.76
5	12.929	BB	0.063	1231	12.823	13.027
6	17.975	BB	0.084	2489	17.843	18.157
7	26.428	BB	0.089	85018	26.19	26.643
8	30.959	BB	0.093	57852	30.743	31.163
9	35.323	BB	0.077	8314	35.187	35.483
10	37.543	BV	0.085	91986	37.313	37.73
11	37.839	VB	0.077	1750	37.73	37.987
12	40.784	BB	0.072	23951	40.623	40.993
13	43.366	BB	0.07	755	43.25	43.493

Figure A5 Methyl ester content of biodiesel from CaO–ZnO (1:3:CP:calcined 800 °C:4h) catalyst.



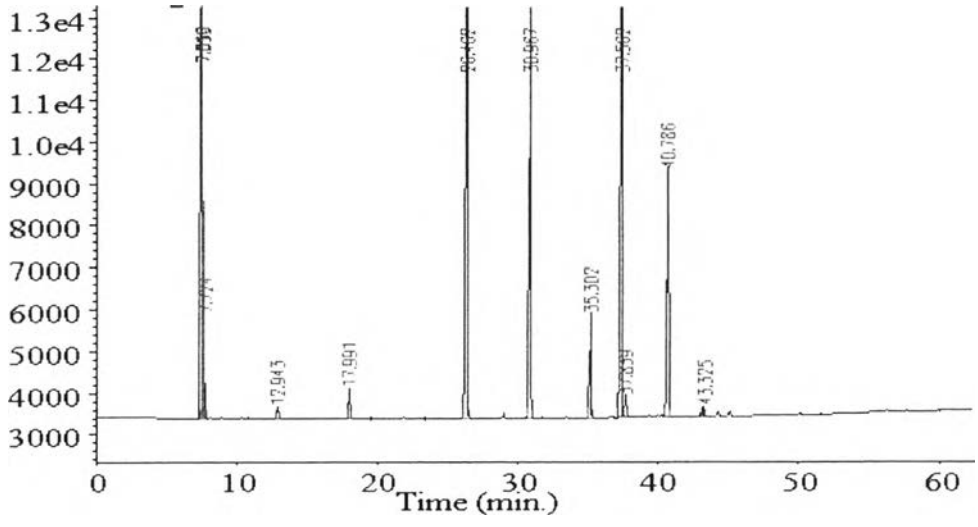
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.508	BHS	0.026	1974077	7.433	7.517
2	7.538	HHS	0.026	4264292	7.517	7.588
3	7.601	HBS	0.028	8625	7.588	7.887
4	7.703	BVT	0.047	6706	7.634	7.757
5	12.891	BB	0.06	1354	12.797	12.99
6	17.905	BB	0.087	2793	17.777	18.06
7	26.349	BB	0.09	98324	26.11	26.593
8	30.875	BB	0.085	64983	30.653	31.08
9	35.23	BB	0.077	10059	35.087	35.427
10	37.466	BV	0.086	110030	37.223	37.637
11	37.759	VB	0.063	2061	37.637	37.897
12	40.698	BB	0.073	28435	40.537	40.85
13	43.283	BB	0.07	950	43.15	43.403

Figure A6 Methyl ester content of biodiesel from CaO–ZnO (1:3:CP:calcined 800 °C:12h) catalyst.



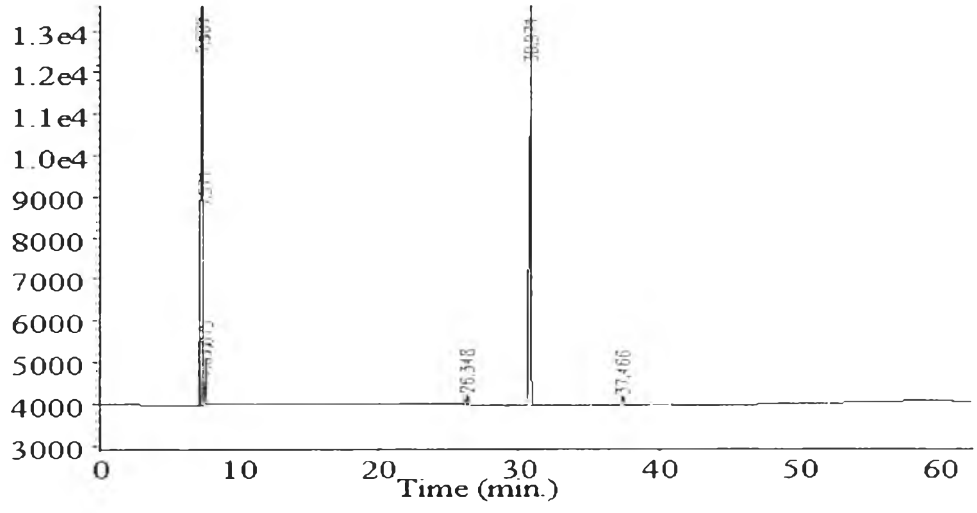
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.503	BHS	0.031	2448572	7.42	7.523
2	7.546	HHS	0.024	4328571	7.523	7.594
3	7.61	HBS	0.026	8876	7.594	7.917
4	7.671	BVT	0.026	204	7.647	7.686
5	7.714	VVT	0.033	752	7.686	7.76
6	12.914	BB	0.062	1417	12.8	12.997
7	17.944	BB	0.082	2928	17.797	18.127
8	26.39	BB	0.095	101852	26.127	26.61
9	30.915	BB	0.088	67552	30.683	31.133
10	35.27	BB	0.077	10149	35.12	35.487
11	37.508	BV	0.089	111058	37.25	37.677
12	37.795	VB	0.076	2094	37.677	37.923
13	40.738	BB	0.076	28649	40.567	40.93
14	43.316	BB	0.08	906	43.183	43.44

Figure A7 Methyl ester content of biodiesel from CaO–ZnO (1:5:CP:calcined 800 °C) catalyst.



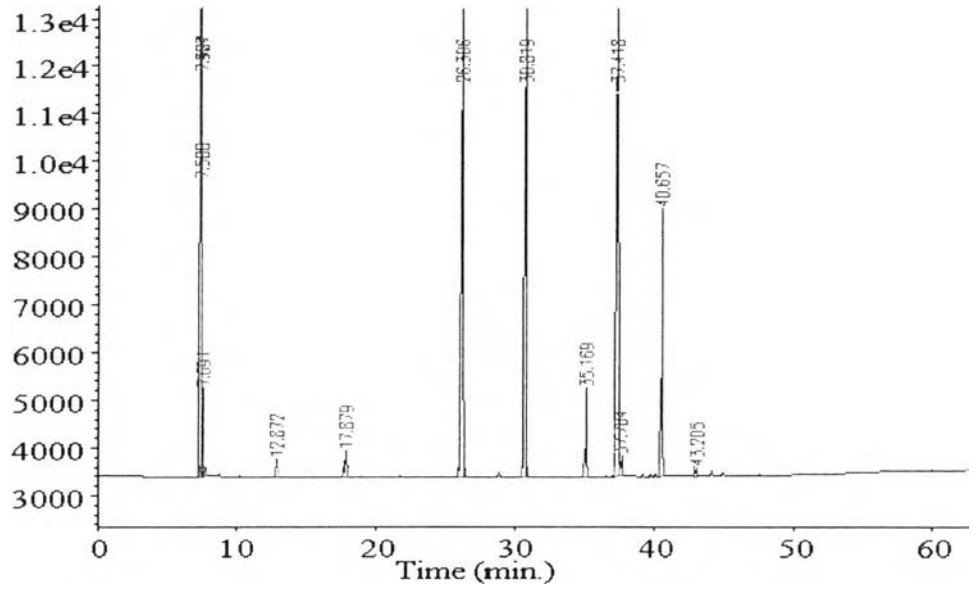
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.516	BHS	0.025	1080048	7.433	7.529
2	7.555	HHS	0.024	5308189	7.529	7.6
3	7.619	HBS	0.026	29458	7.6	7.833
4	7.724	BBT	0.037	5759	7.657	7.777
5	12.943	BB	0.049	945	12.863	13.053
6	17.991	BB	0.075	3522	17.87	18.11
7	26.462	BB	0.087	123661	26.18	26.667
8	30.967	BB	0.084	76373	30.733	31.173
9	35.302	BB	0.075	13383	35.143	35.453
10	37.562	BV	0.089	131938	37.3	37.72
11	37.839	VB	0.07	2426	37.72	37.977
12	40.786	BB	0.074	29587	40.613	40.957
13	43.325	BB	0.08	1275	43.217	43.447

Figure A8 Methyl ester content of biodiesel from CaO–ZnO (1:1;CP:calcined 800 °C) catalyst.



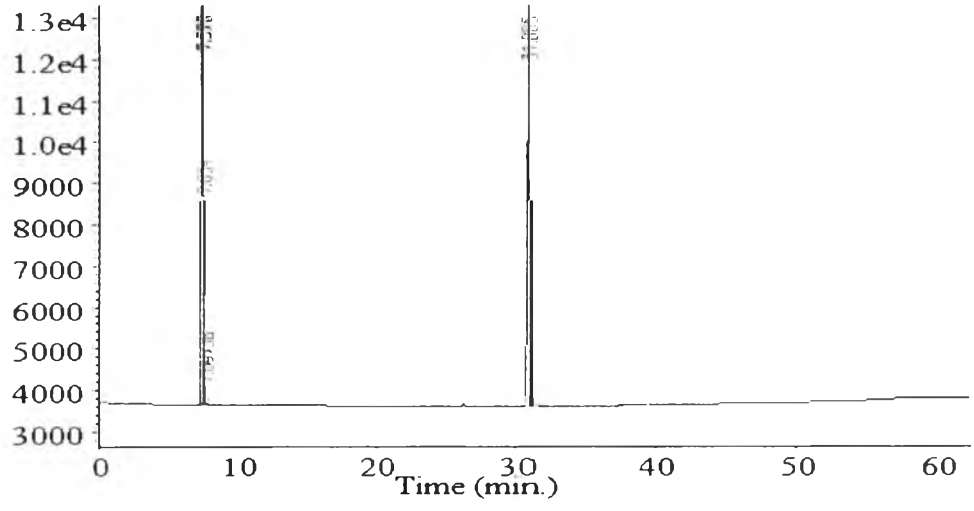
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.464	BHS	0.031	2620628	7.387	7.485
2	7.507	HHS	0.023	4025148	7.485	7.555
3	7.571	HBS	0.027	8739	7.555	7.767
4	7.632	BVT	0.029	810	7.603	7.647
5	7.675	VBT	0.033	2201	7.647	7.72
6	26.348	BB	0.081	1501	26.227	26.503
7	30.971	BB	0.089	79950	30.727	31.15
8	37.466	BB	0.075	1125	37.357	37.6

Figure A9 Methyl ester content of biodiesel from CaO–ZnO (1:3;IWI:calcined 600 °C) catalyst.



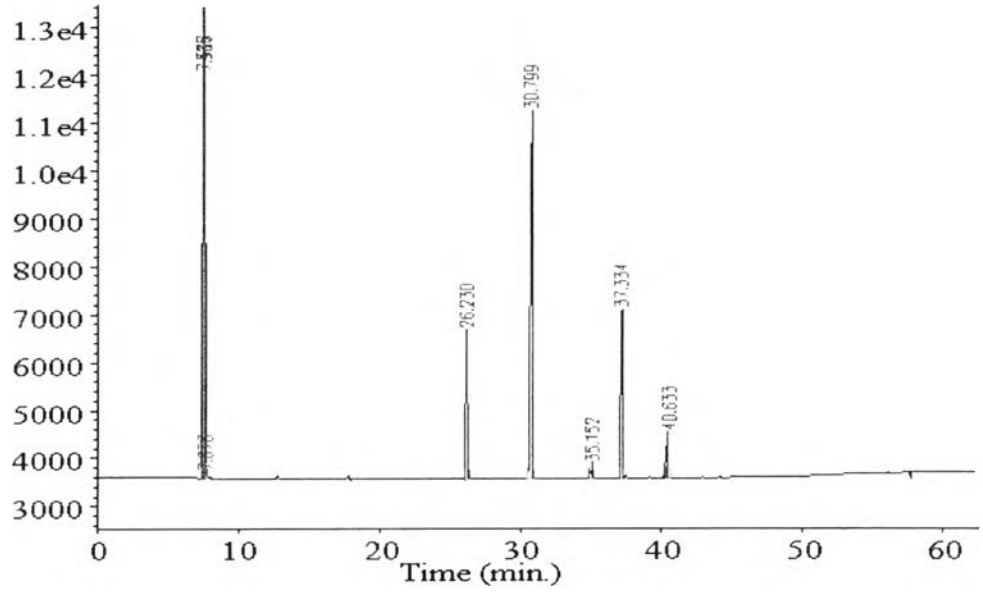
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.487	BHS	0.027	2046039	7.41	7.502
2	7.524	HHS	0.024	4638069	7.502	7.572
3	7.588	HBS	0.032	12167	7.572	7.863
4	7.691	BVT	0.042	5236	7.621	7.74
5	12.872	BB	0.057	1469	12.77	12.973
6	17.879	BB	0.081	2971	17.747	18.03
7	26.306	BB	0.089	103317	26.05	26.55
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

Figure A10 Methyl ester content of biodiesel from CaO–ZnO (1:3:IWI:calcined 800 °C:8h) catalyst.



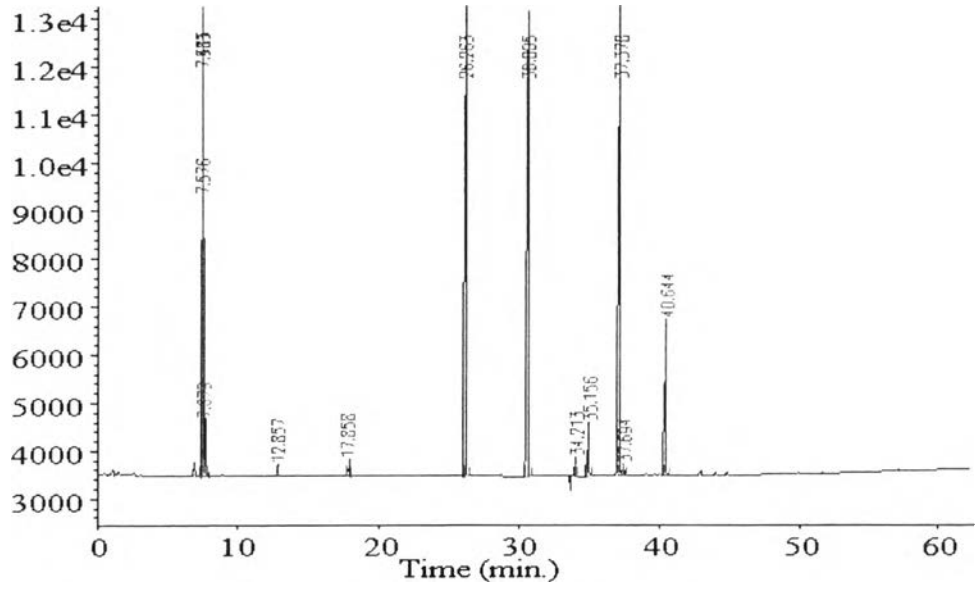
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.527	BHS	0.03	2567478	7.423	7.547
2	7.57	HHS	0.024	4460583	7.547	7.618
3	7.634	HBS	0.027	9189	7.618	7.907
4	7.697	BVT	0.028	624	7.668	7.71
5	7.738	VVT	0.034	1739	7.71	7.783
6	31.005	BB	0.09	73298	30.737	31.217

Figure A11 Methyl ester content of biodiesel from CaO–ZnO (1:3;IWI:calcined 900 °C) catalyst.



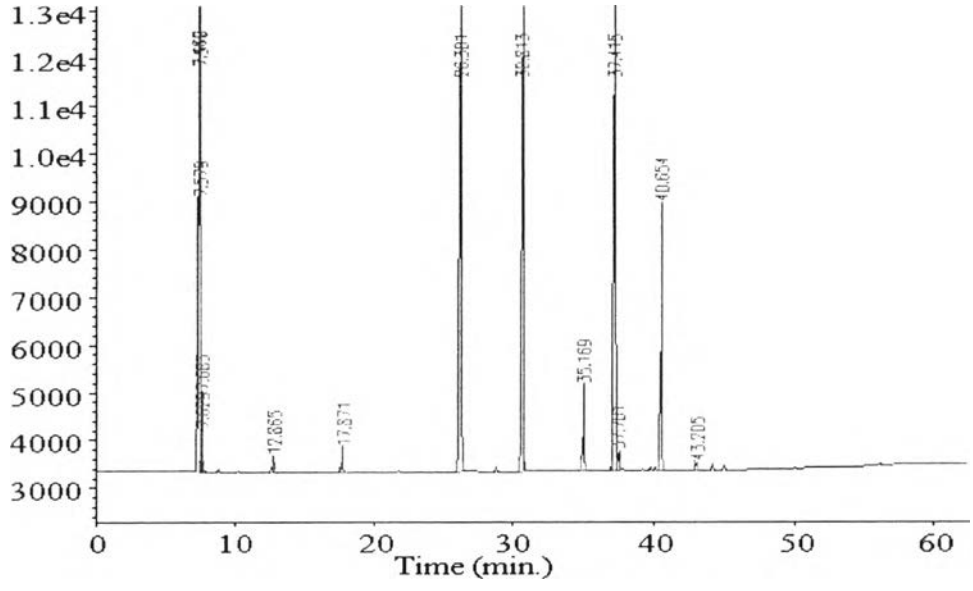
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.487	BHS	0.026	2239046	7.42	7.501
2	7.516	HBS	0.025	2501090	7.501	7.78
3	7.676	BBT	0.043	203	7.631	7.707
4	26.23	BB	0.085	18799	26.063	26.437
5	30.799	BB	0.08	45035	30.6	31.023
6	35.152	BB	0.08	1848	35.047	35.297
7	37.334	BB	0.081	19398	37.173	37.5
8	40.633	BB	0.069	5059	40.51	40.787

Figure A12 Methyl ester content of biodiesel from CaO–ZnO (1:3:IWI:calcined 800 °C:2h) catalyst.



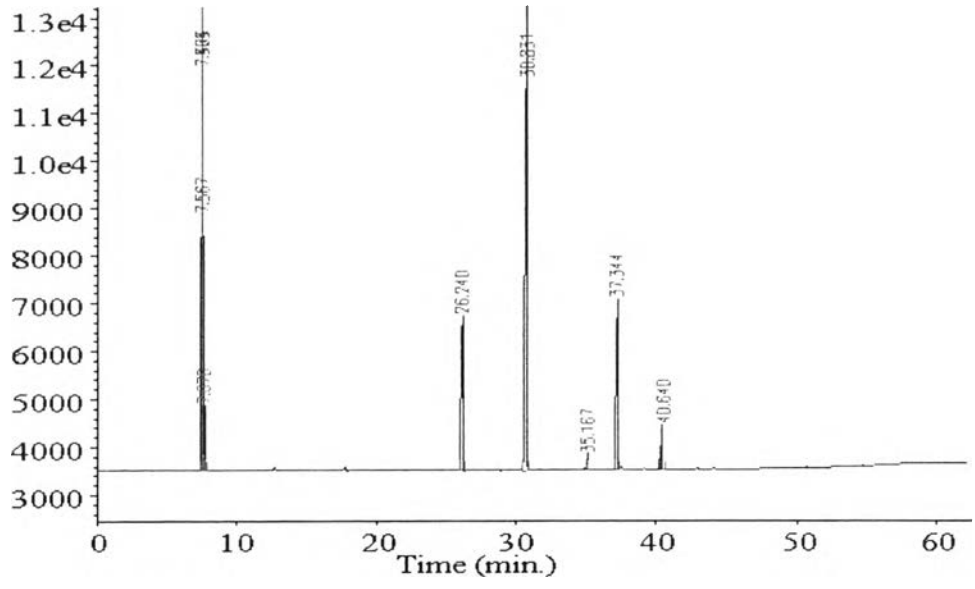
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.481	BHS	0.027	2021927	7.3	7.491
2	7.513	HHS	0.025	4578793	7.491	7.561
3	7.576	HBS	0.026	10860	7.561	7.86
4	7.679	BVT	0.043	3469	7.612	7.737
5	12.857	BB	0.058	991	12.757	12.963
6	17.858	BB	0.075	1881	17.74	17.997
7	26.263	BB	0.084	63080	26.06	26.497
8	30.805	BB	0.089	59037	30.573	30.973
9	34.213	BB	0.009	109	34.153	34.24
10	35.156	BB	0.068	5984	35.013	35.34
11	37.378	BB	0.078	64365	37.16	37.567
12	37.694	BB	0.073	1198	37.59	37.817
13	40.644	BB	0.077	16855	40.487	40.807

Figure A13 Methyl ester content of biodiesel from CaO–ZnO (1:3:IWI:calcined 800 °C:4h) catalyst.



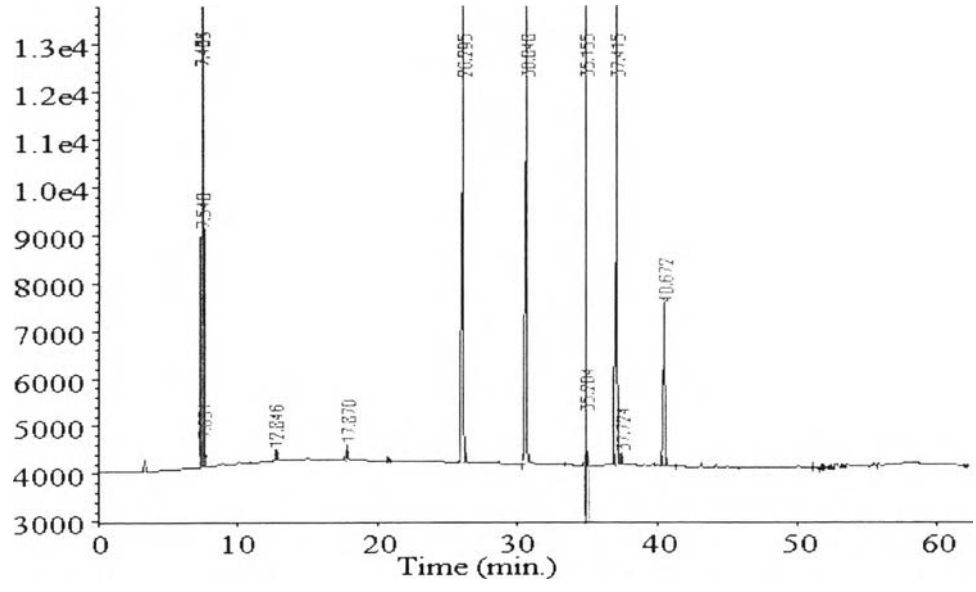
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.462	BHS	0.031	2387969	7.393	7.49
2	7.516	HHS	0.024	4146563	7.49	7.562
3	7.579	HBS	0.03	12457	7.562	7.773
4	7.629	BVT	0.026	702	7.61	7.653
5	7.683	VBT	0.031	2913	7.653	7.727
6	12.865	BB	0.058	1411	12.75	12.95
7	17.871	BB	0.078	2968	17.737	18.02
8	26.301	BB	0.09	103894	26.03	26.513
9	30.813	BB	0.085	65365	30.587	31.013
10	35.169	BB	0.075	10297	35.017	35.337
11	37.415	BV	0.088	113808	37.167	37.583
12	37.701	VB	0.075	2122	37.583	37.82
13	40.654	BB	0.073	29556	40.47	40.81
14	43.205	BB	0.067	936	43.1	43.323

Figure A14 Methyl ester content of biodiesel from CaO–ZnO (1:3:IWI:calcined 800 °C:12h) catalyst.



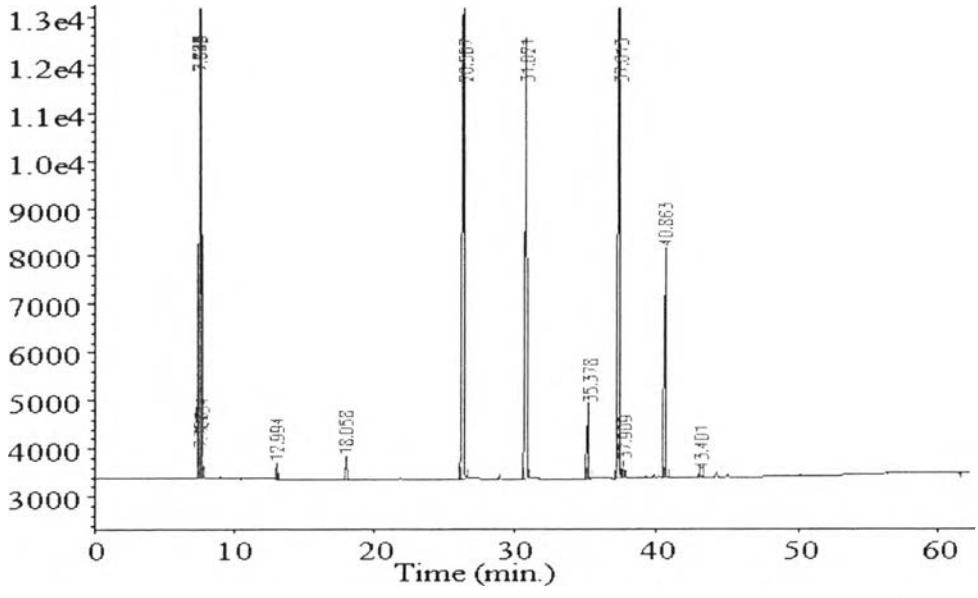
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.475	BHs	0.025	1998539	7.393	7.483
2	7.504	HHS	0.024	4858135	7.483	7.553
3	7.567	HBS	0.027	9767	7.553	7.85
4	7.67	BVT	0.044	3999	7.604	7.727
5	26.24	BB	0.079	18999	26.08	26.437
6	30.831	BB	0.084	71363	30.59	31.05
7	35.167	BB	0.07	1876	35.057	35.274
8	37.344	BB	0.077	18891	37.197	37.517
9	40.64	BB	0.071	4929	40.503	40.783

Figure A15 Methyl ester content of biodiesel from CaO–ZnO (1:5:IWI:calcined 800 °C) catalyst.



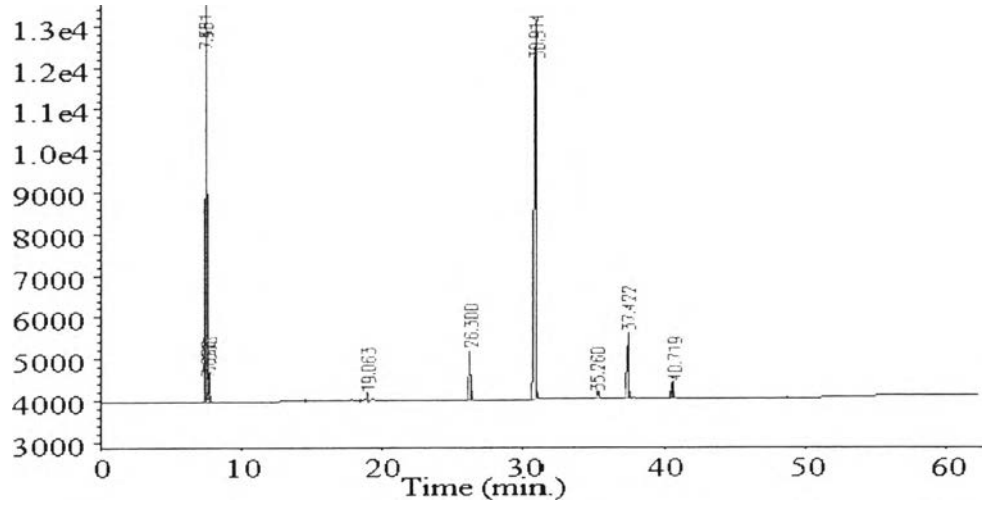
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.451	BHS	0.026	2187599	7.337	7.464
2	7.485	HHS	0.024	4555692	7.464	7.534
3	7.548	HBS	0.026	8985	7.534	7.827
4	7.651	BVT	0.042	1552	7.586	7.705
5	12.846	BB	0.059	938	12.723	12.947
6	17.87	BB	0.081	1869	17.697	17.993
7	26.295	BB	0.088	65564	26.037	26.5
8	30.848	BB	0.081	67303	30.483	31.047
9	35.155	BV	0.021	17504	35.03	35.177
10	35.204	PB	0.053	18204	35.177	35.337
11	37.415	BV	0.079	68781	37.163	37.583
12	37.724	VB	0.082	1414	37.583	37.857
13	40.672	BB	0.076	17678	40.497	40.843

Figure A16 Methyl ester content of biodiesel from CaO–ZnO (1:1:IWI:calcined 800 °C) catalyst.



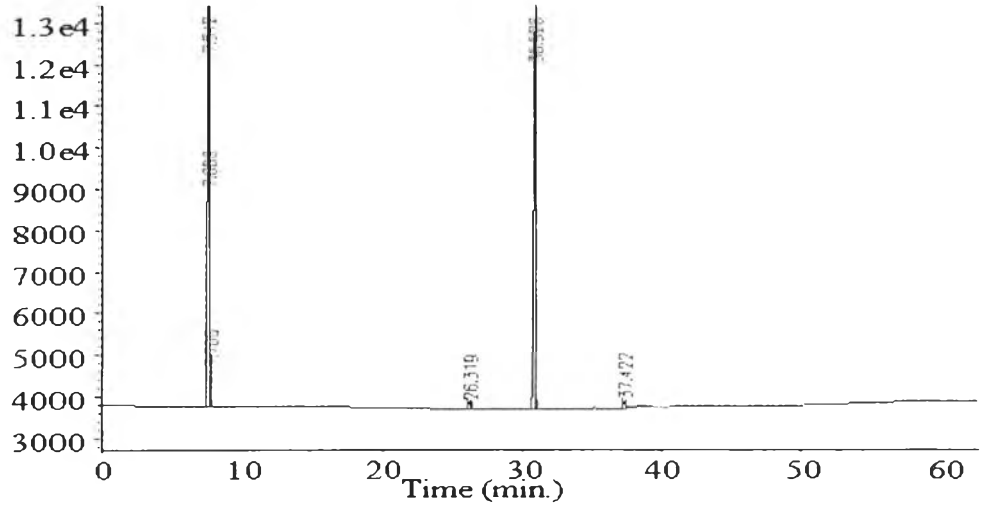
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.538	BHS	0.03	2226922	7.457	7.561
2	7.585	HHS	0.024	3687532	7.561	7.629
3	7.649	HBS	0.027	21433	7.629	7.923
4	7.706	BVT	0.028	593	7.685	7.727
5	7.754	VVT	0.033	1663	7.727	7.8
6	12.994	BB	0.058	1306	12.873	13.083
7	18.058	BB	0.078	2577	17.913	18.17
8	26.507	BB	0.086	87100	26.27	26.71
9	31.021	BB	0.082	54064	30.8	31.197
10	35.378	BB	0.073	8408	35.23	35.527
11	37.613	BV	0.085	92976	37.377	37.787
12	37.909	VB	0.082	1841	37.787	38.05
13	40.863	BB	0.076	24089	40.717	41.047
14	43.401	BB	0.077	790	43.277	43.503

Figure A17 Methyl ester content of biodiesel from CaO–ZnO (3:1:IWI:calcined 800 °C) catalyst.



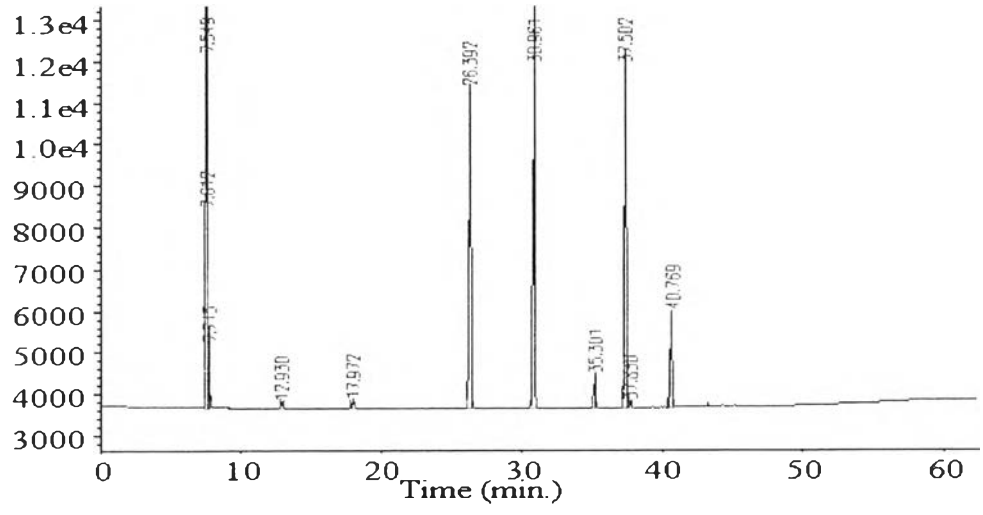
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.461	BHS	0.03	2553895	7.38	7.481
2	7.501	HBS	0.025	2971795	7.481	7.867
3	7.628	BVT	0.028	641	7.602	7.645
4	7.668	VVT	0.034	1272	7.645	7.713
5	19.063	PB	0.01	71	18.983	19.073
6	26.3	BB	0.094	8094	26.127	26.527
7	30.914	BB	0.09	58807	30.65	31.133
8	35.26	BB	0.074	920	35.117	35.4
9	37.422	BB	0.071	8805	37.243	37.627
10	40.719	BB	0.088	2168	40.57	40.86

Figure A18 Methyl ester content of biodiesel from CaO–ZnO (1:3;CP:spent 1) catalyst.



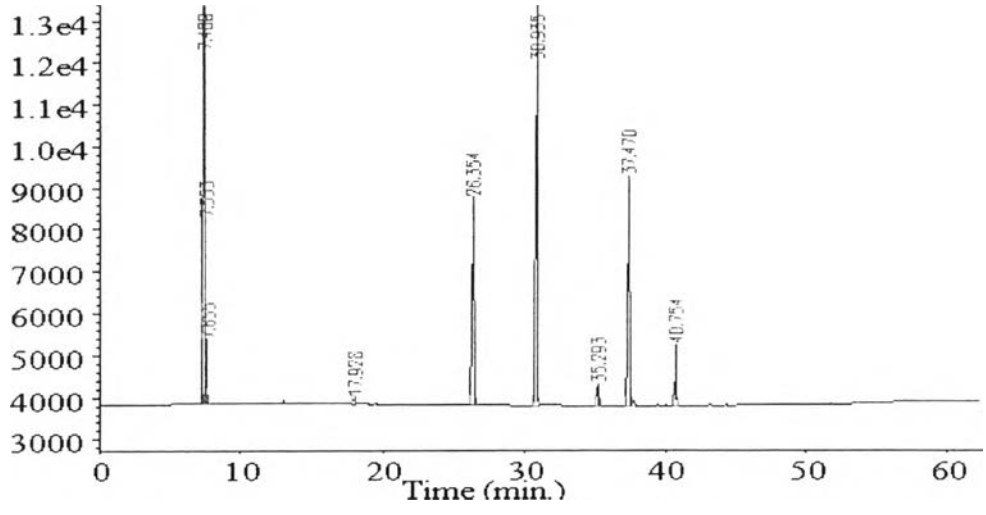
Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.542	BHS	0.032	6844199	7.44	7.592
2	7.606	HBS	0.031	10230	7.592	7.8
3	7.708	BBT	0.043	2711	7.644	7.76
4	26.319	BB	0.079	1210	26.18	26.487
5	30.926	BB	0.086	63575	30.67	31.127
6	37.422	BB	0.078	1006	37.32	37.563

Figure A19 Methyl ester content of biodiesel from CaO–ZnO (1:3;CP:spent 2) catalyst.



Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.549	BHS	0.034	6611851	7.443	7.598
2	7.612	HBS	0.032	9550	7.598	7.893
3	7.715	BVT	0.045	4770	7.647	7.77
4	12.93	BB	0.06	664	12.837	13.007
5	17.972	BB	0.085	1348	17.823	18.11
6	26.392	BB	0.079	48113	26.147	26.607
7	30.961	BB	0.086	66541	30.69	31.173
8	35.301	BB	0.074	4726	35.123	35.47
9	37.502	BB	0.079	49348	37.31	37.683
10	37.83	BB	0.076	928	37.723	37.943
11	40.769	BB	0.084	12667	40.637	40.917

Figure A20 Methyl ester content of biodiesel from CaO–ZnO (1:3;IWI:spent 1) catalyst.



Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	7.458	BHS	0.026	2176606	7.373	7.469
2	7.489	HHS	0.024	4006301	7.469	7.538
3	7.553	HBS	0.026	8123	7.538	7.757
4	7.655	BBT	0.045	4582	7.586	7.707
5	17.928	BB	0.081	888	17.81	18.073
6	26.354	BB	0.09	31248	26.17	26.607
7	30.935	BB	0.088	60756	30.71	31.183
8	35.293	BB	0.078	2973	35.183	35.453
9	37.47	BB	0.085	30601	37.3	37.69
10	40.754	BB	0.076	7801	40.613	40.91

Figure A21 Methyl ester content of biodiesel from CaO–ZnO (1:3;IWI:spent 2) catalyst.

The composition of the reaction mixture samples was determined by the somewhat modified HPLC method of Holčapek *et al.*, (1999) using a Perkin Elmer High Performance Liquid Chromatography.

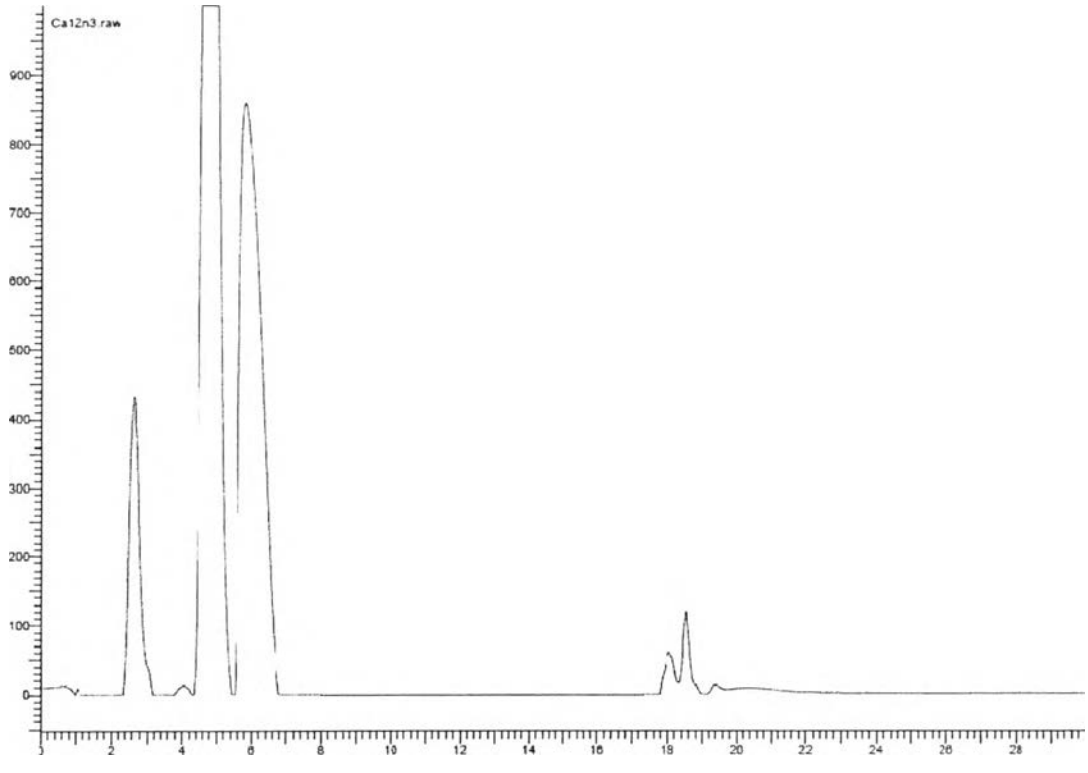


Figure A22 The chromatogram of CaO–ZnO (1:3, CP) catalyst from High Performance Liquid Chromatography (HPLC).

Table A1 Raw data of CaO–ZnO (1:3, CP) catalyst from HPLC

Time [min]	Area	Height	Area [%]	Norm. Area [%]	BL	Area/Height [s]
0.676	288249.6	8439.12	0.32	0.32	BB	34.1564
1.045	38979.6	9221.36	0.04	0.04	BB	4.2271
2.651	8443905	432881.8	9.39	9.39	BB	19.5063
4.06	232540	11841.28	0.26	0.26	BB	19.6381
4.567	40632136	999996	45.18	45.18	BB	40.6323
5.831	36490399	859656.1	40.57	40.57	BB	42.4477
18.038	1169095	60814.24	1.3	1.3	BV	19.224
18.531	1630929	120519.9	1.81	1.81	VB	13.5324
19.385	268581.3	12780.26	0.3	0.3	BV	21.0153
20.378	744881.7	7921.35	0.83	0.83	VB	94.0347
24.302	84.8	34.85	9E-05	9.E-05	BB	2.4335
25.065	115.99	31.82	0	0	BV	3.6456
25.159	101.21	37.09	0	0	VB	2.7285
26.056	117.8	33.04	0	0	BB	3.5649
26.818	102.8	26.14	0	0	BB	3.9324
27.638	97.2	31.07	0	0	BB	3.1282
28.117	109.2	33.24	0	0	BB	3.2854
28.291	140.6	50.61	0	0	BB	2.7782
28.967	73.4	25.01	8E-05	8.E-05	BB	2.9352

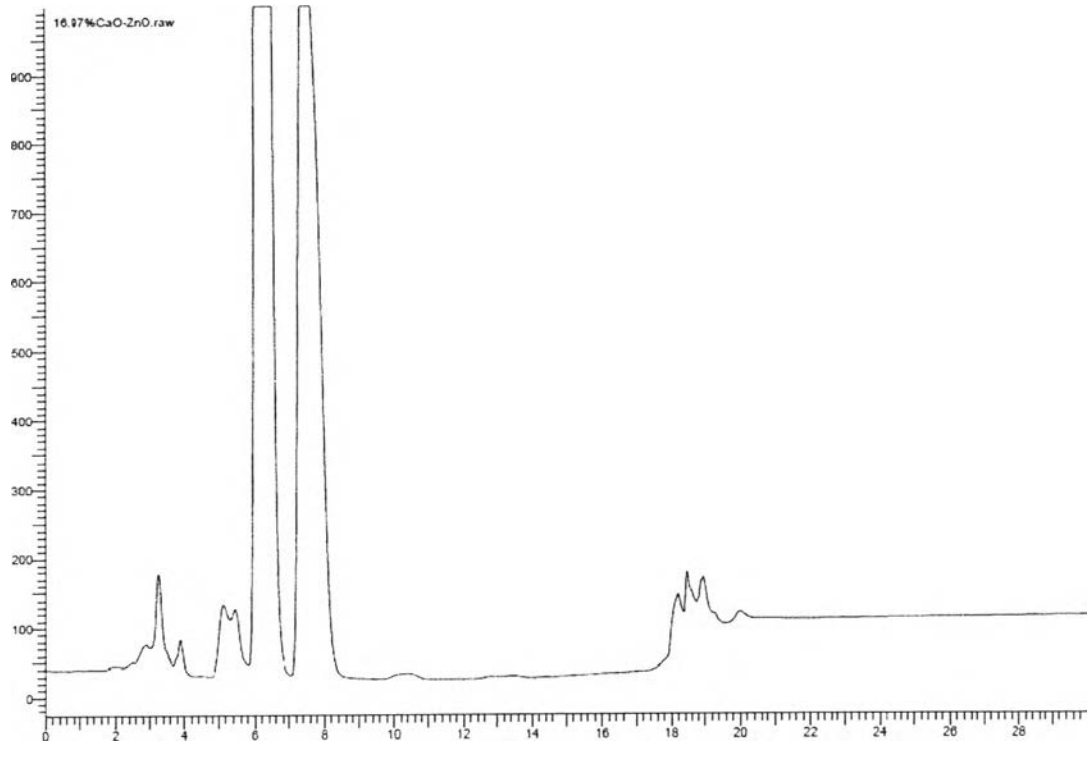


Figure A23 The chromatogram of CaO–ZnO (1:3, IWI) from High Performance Liquid Chromatography (HPLC).

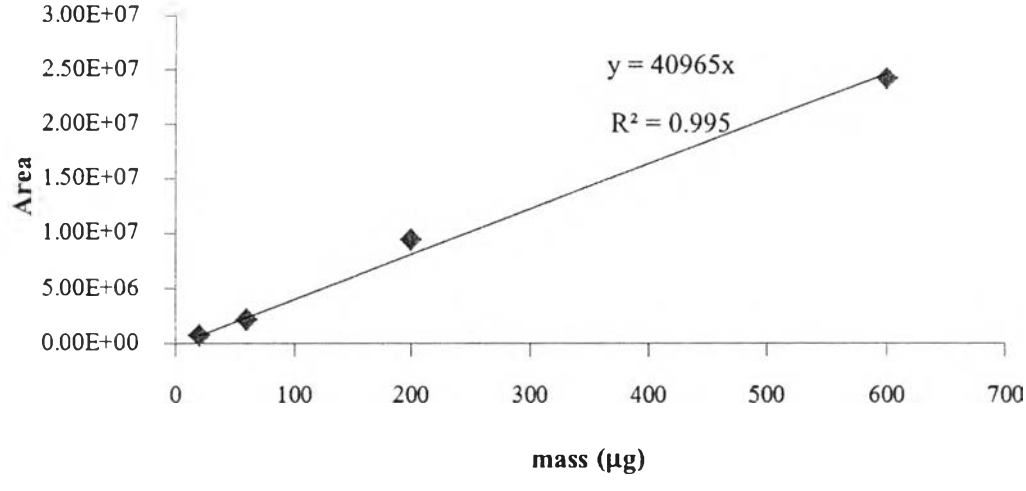
Table A2 Raw data of CaO–ZnO (1:3, IWI) catalyst from HPLC

Time [min]	Area	Height	Area [%]	Norm. Area [%]	BL	Area/Height [s]
1.923	256710.9	7540.3	0.27	0.27	BV	34.0452
2.089	103101.8	7777.93	0.11	0.11	VV	13.2557
2.482	204147.8	15480.78	0.21	0.21	VV	13.1872
2.913	943406.8	42822.67	0.99	0.99	VV	22.0305
3.271	2399033	144777.2	2.52	2.52	VV	16.5705
3.897	665994	51488.79	0.7	0.7	VB	12.9347
4.473	10932	833.09	0.01	0.01	BB	13.1222
5.138	1925231	104038.9	2.02	2.02	BV	18.5049
5.453	1744597	97508.04	1.83	1.83	VV	17.8918
5.993	37471663	970000.2	39.41	39.41	VB	38.6306
7.32	40742843	970129.4	42.85	42.85	BB	41.9973
10.404	361533.2	8842.08	0.38	0.38	BB	40.8878
11.323	68.4	20.3	7.E-05	7.E-05	BB	3.3694
12.817	103551.5	3470.03	0.11	0.11	BV	29.8416
13.452	113689.3	3523.65	0.12	0.12	VB	32.2647
18.191	1867234	92037.99	1.96	1.96	BV	20.2876
18.448	2096180	119484.8	2.2	2.2	VV	17.5435
18.955	2188518	100812.6	2.3	2.3	VV	21.7088
19.262	613372.4	43278.47	0.65	0.65	VV	14.1727
19.995	1090507	30309.04	1.15	1.15	VV	35.9796
20.759	113255.8	3506.23	0.12	0.12	VB	32.3014
24.274	38962.52	388.96	0.04	0.04	BV	100.1719
24.751	9438.05	308.9	0.01	0.01	VV	30.5535
25.162	6461.76	252.55	0.01	0.01	VV	25.5857
26.434	14951.07	163.27	0.02	0.02	VV	91.5753
28.848	6010.78	36.75	0.01	0.01	VB	163.5625

Calibration curve

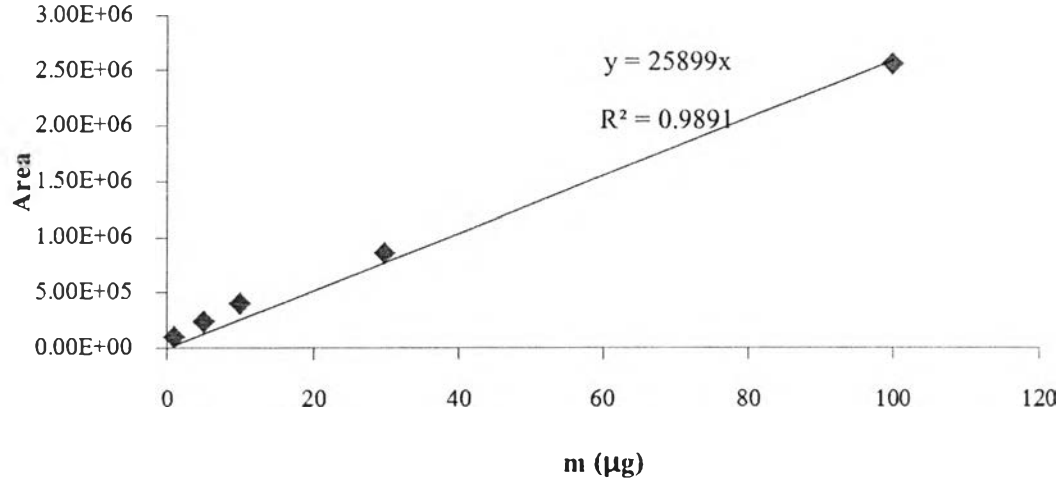
Ethyl oleate

Amount of std	Area	Rs
20	824370.4	41218.52
60	2221263.77	37021.06283
200	9424591.97	47122.95985
600	24191677.4	40319.46233
	Average	41420.50125



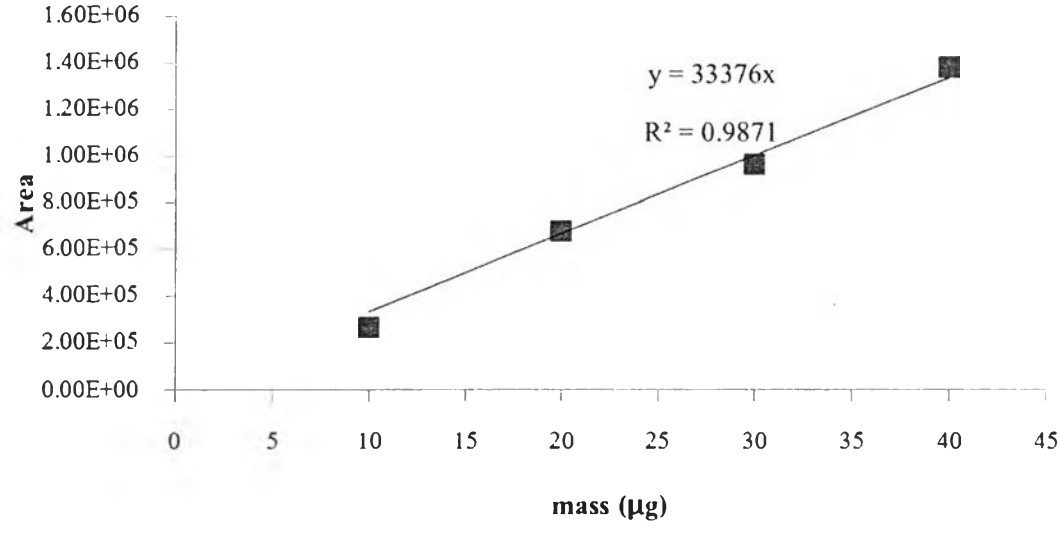
Triglyceride

Amount of std	Area	Rf
1	98460	98460
5	234123.6	46824.72
10	400853.94	40085.394
30	852209.6	28406.98667
	Average	47849.84533



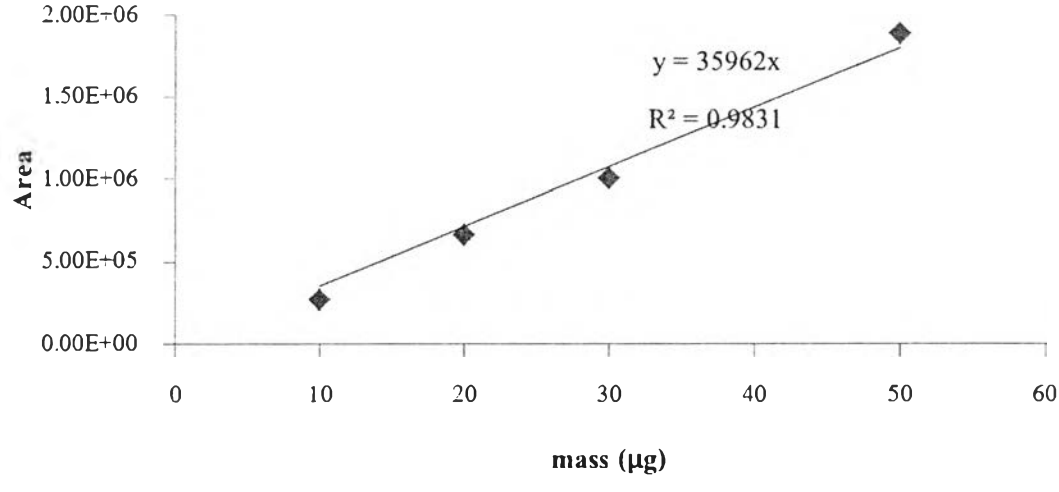
Diglyceride

Amount of std	Area	Rf
10	265421.7	26542.17
20	675897.775	33794.88875
30	959131.55	31971.05167
40	1379564.69	34489.11725
	Average	31699.30692



Monoglyceride

Amount of std	Area	Rf
10	272161.26	27216.126
20	664779.56	33238.978
30	1001505.8	33383.52667
50	1883756.535	37675.1307
	Average	32878.44034



CURRICULUM VITAE

Name: Mr. Sirichai Chantara-arpornchai

Date of Birth: October 22, 1987

Nationality: Thai

University Education:

2006–2010 Bachelor Degree of Chemical Engineering, Faculty of Engineering, Mahidol University, Nakornpathom, Thailand

Work Experience:

March – May 2009 Position: Internship Student

Company Name: Absolute Denim Co., Ltd.

Proceedings:

1. Chantara-arpornchai, S.; Luengnaruemitchai, A.; and Jai-In, S. (2012, April 11-13) Biodiesel Production from Palm Oil using Heterogeneous Base Catalyst. Proceedings of the 32th ICCBEE 2012 : International Conference on Chemical, Biological and Environmental Engineering, Venice, Italy.
2. Chantara-apornchai, S., Luengnaruemitchai, A., and Jai-In, S. (2012, April 24) Biodiesel Production from Palm Oil Using CaO–ZnO Catalysts. Proceedings of the 3rd Research Symposium on Petroleum, Petrochemical, and Advanced Materials and 18th PPC Symposium on Petroleum, Petrochemical, and Polymers, Bangkok, Thailand.