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APPENDICES

APPENDIX A

Raw Data in the Characterization of Vegetable Oil

A.1 Acid Value (Free Fatty Acid Content), AOCS Official Method Cd 3d-63

The acid value is the number of milligrams of potassium hydroxide necessary to neutralize the free acids in 1 gram of sample. With samples that contain virtually no free acids other than fatty acids, the acid value may be directly converted by means of suitable factor to percent free fatty acids.

Apparatus

1. Erlenmeyer flasks 250 ml
2. Burette—25 ml

Reagents and chemicals

1. Potassium hydroxide (KOH), 0.1 N—baker "Reagent Grade"
2. Solvent mixture consisting of equal parts by volume of isopropyl alcohol (AOCS Specification H 18-58) and toluene (AOCS Specification H 19-58)
3. Phenolphthalein indicator solution—1.0% in isopropyl alcohol

Procedure

1. Add indicator solution to the required amount of solvent in ratio of 2 ml and neutralize with alkali to a faint but permanent pink color.
2. Weight the 20 g of sample into an Erlenmeyer flask.
3. Add 125 ml of the neutralized solvent mixture.
4. Shake the sample vigorously while titrating with standard alkali to the first permanent pink color of the same intensity as that of the neutralized solvent before the latter was added to the sample. The color must persist for 30 sec.

Calculations

Acid value (A.V.), mg KOH/g of sample $= \frac{(A-B) \times N \times 56.1}{W}$

Where A = volume, ml of standard alkali used in the titration

B = volume, ml of standard alkali used in the titrating blank

N = normality of standard alkali

W = mass, grams of sample

Table A.1 Acid Value using AOCS Official Method Cd 3d-63

	1	2	3
Weight of soybean oil, g	20.0042	20.0109	20.0117
Volume of solvent mixture, ml	125	125	125
Cone, of KOH, N	0.1	0.1	0.1
Volume of KOH, used in sample, ml	0.55	0.60	0.60
Volume of KOH,used in Blank, ml	0.15	0.15	0.15
Acid Value (A.V.), mg KOH/g	0.1122	0.1262	0.1262
Average Acid Value, mg KOH/g	$0.1215 \approx 0.12$		

Table A.2 Moisture content determination using AOCS Aa 3-38

	Soybean Oil		
	1	2	3
Wt. Oil, g	5.0064	5.0037	5.0042
Initial Wt. Oil + Dish, g	48.2731	47.9565	48.3895
Final Wt. Oil + Dish, g	48.2136	47.8962	48.3374
Moisture Content, %	1.1885	1.2051	1.0411
Ave. Moisture Content, %	1.14		

Table A.3 Transesterification of Crude and Refined Vegetable Oils with Methanol [41]

Oil	Type	Acid Value	Phosphorous (ppm)	Methyl ester yield (wt%)
Peanut	Crude	6.66	264	67
	Refined	0.08	5	95
Soybean	Crude	1.67	953	83
	Refined	0.12	1	98
Safflower	Crude	0.44	4	86
	Refined	-	-	-
Cottonseed	Crude	0.28	<1	84
	Refined	0.06	0.5	93
Sunflower	Crude	1.64	85	81
	Refined	0.08	0.7	97

Table A.4 Comparison of Some Typical Properties of Diesel, Soybean Oil [42]

Properties	No.2 Diesel	Soybean oil		
		Oil	Methyl ester	Ethyl ester
Specific gravity	0.8495	0.92	0.886	0.881
Viscosity at 40◦ C,mm2/s	2.98	33	3.891	4.493
Cloud point, ◦C	-12	-4	3	0
Pour point, ◦C	-23	-12	-3	-3
Flash point, ◦C			188	171
Boiling point ◦C	191		339	357
Water & sediment, vol %	0.005		0.005	0.005
Carbon residue, wt%	0.16		0.068	0.071
Ash, wt %	0.002		0	0
Sulfur, wt %	0.036	0.01	0.012	0.008
Cetane number	49	38	55	53
Copper corrosion	1A	39.3	1A	1A
Higher heating value, MJ/kg	45.42	36.2	39.77	39.96
MJ/L	38.58		35.24	35.20

Table A.5 Fuel properties of fats and oils: Fuel-related properties and iodine values of various fats and oil [42]

Oil or Fat	Iodine Value	Cetane Number	High Heating Value	Viscosity	Cloud Point	Pour Point	Flash Point
Babassu	10-18	38	-	-	-	-	-
Castor	82-88	-	39500	297 (38°C)	-	-31.7	260
Coconut	6-12	-	-	-	-	-	-
Corn	103-140	37.6	39500	34.9 (38°C)	-1.1	-40.0	277
Cottonseed	90-119	41.8	39468	33.5 (38°C)	1.7	-15.0	234
Crambe	93	44.6	40482	53.6 (38°C)	10.0	-12.2	274
Linseed	168-204	34.6	39307	27.2 (38°C)	1.7	-15.0	241
Olive	75-94	-	-	-	-	-	-
Palm	35-67	42	-	-	-	-	-
Peanut	80-106	41.8	39782	39.6 (38°C)	12.8	-6.7	271
Rapeseed	94-120	37.6	39709	37.0 (38°C)	-3.9	-31.7	246
Safflower	126-152	41.3	39519	31.3 (38°C)	18.3	-6.7	260
High-oleic safflower	90-100	49.1	39516	41.2 (38°C)	-12.2	-20.6	293
Sesame	104-120	40.2	39349	35.5 (38°C)	-3.9	-9.4	260
Soybean	117-143	37.9	39623	32.6 (38°C)	-3.9	-12.2	254
Sunflower	110-143	37.1	39575	37.1 (38°C)	7.2	-15.0	274
Tallow	35-48	-	40054	51.15 (40 °C)	-	-	201
No.DF	-	47	45343	2.7 (38°C)	15.0	-33.0	52

APPENDIX B

Raw Data for heterogeneous Transesterification

B.1 Calculation of the methyl ester content

Internal standardization is widely used in quantitative analysis because this method shows higher precision than external standardization by 1.4 times. This method is performed by adding internal standard into standard solution and sample solution with same amount. The concept is to reduce the error from each step of analysis.

Properties of suitable internal standard:

1. Must be completely separated from other compounds and its peak should not be superimposed with others.
2. Internal standard should have the chemical structure similar to the sample.
3. Internal standard should not be found in the sample solution.
4. The amount of internal standard added into the sample solution should be equal.
5. Highly purified.
6. High stable and not react with other compounds found in sample as well as stationary phase of the column.

Compensated normalization is a method that employs response factor of the chemicals for better result. Response factor can be found by injection of standard mixture (internal standard and solvent), of which types and amount are known. Then, the mass ratio of the standards and the ratio of the peak area of the corresponding standards are used to calculate the response factor. The response factor can then be used to correct peak area of each compound in the sample. Subsequently percentage of each compound within the sample can be calculated correctly.

Procedure:

1. Mixture of the solvent (i.e. n-heptane) and an internal standard (i.e. methyl decanoate), was prepared by mixing these components at the weight ratio of 20:1.
2. The solution was then mixed with methyl ester standard at the weight ratio of 1.5:1. Then, 0.5µl of the final mixture was injected to GC, in order to determine the response factor (C_{SD}) of each standard sample, according to Equation B1.

$$\frac{M_{SD}}{M_{\text{int}}} = C_{SD} \times \frac{A_{SD}}{A_{\text{int}}}$$

$$C_{SD} = \frac{A_{\text{int}}}{A_{SD}} \times \frac{M_{SD}}{M_{\text{int}}} \qquad \text{(B1)}$$

Where: M_{SD} = Mass of methyl ester standard, g
M_{int} = Mass of internal standard, g
A_{SD} = GC peak area of methyl ester standard
A_{int} = GC peak area of internal standard
C_{SD} = Response factor for methyl ester

This process was repeated for all methyl ester standards.

3. After obtaining the C_{SD} for all methyl ester standards, the procedure was repeated but the biodiesel product was used instead of the methyl standard. Then, the mass of each methyl ester in the sample could be calculated by Equation B2.

$$\frac{M_{ME}}{M_{\text{int}}} = C_{SD} \times \frac{A_{ME}}{A_{\text{int}}}$$

$$M_{ME} = C_{SD} \times \frac{A_{ME}}{A_{\text{int}}} \times M_{\text{int}} \qquad \text{(B2)}$$

Where: M_{ME} = Mass of the interested methyl ester in the sample, g
A_{ME} = GC peak area of the interested methyl ester from the sample

4. The total methyl ester content could be calculated by the summation of mass of all methyl esters in the sample divided by mass of the sample, as show in Equation B3.

$$\%ME\ content = \frac{\sum M_{ME}}{M_{sample}} \times 100 \qquad \text{(B3)}$$

Calculation example

- To calculation the response factor for methyl palmitate (C_{SDp}).

According to the preparation of the standard solution, 1.0384 g of methyl palmitate was mixed with 0.0792 g of methly decanoate. It should be noted that the solution of methly decanoate in n-heptane was first prepared from 1.0933 g methly decanoate and 19.9126 g of n-heptane

After the GC injection, the peak areas for methly decanoate and methyl pal mitate are 5.0356 and 64.1774, respectively.

From Equation B1,

$$C_{SDp} = \frac{A_{\text{int}}}{A_{SDp}} \times \frac{M_{SDp}}{M_{\text{int}}}$$

$$= \frac{5.0356}{64.1774} \times \frac{1.0384}{0.0792}$$

$$= 1.0281$$

Table B.1 GC data and the calculation of the response factor of methyl palmitate standard ($C_{SDp.}$)

No.	Peak area of GC		Response factor of methyl palmitate standard(C_{SDp})
	int-SD.	SD_p.	
1	5.0356	64.1774	1.0281
2	5.1244	64.8464	1.0067
3	5.0925	64.6904	1.0024
		Average C_{SDp}	1.0124

- To calculation the mass of methyl palmitate in the sample

After the analysis of the product from Transesterification using commercial ZnO catalyst, the following data for methyl palmitate were obtained.

GC peak area of methyl palmitate = 1.2278
GC peak area of internal standard = 5.1624
Mass of internal standard = 0.0853 g

From Equation B2,

$$M_{MEp} = C_{SDp} \times \frac{A_{MEp}}{A_{int}} \times M_{int}$$

$$= 1.0124 \times \frac{1.2278}{5.1624} \times 0.0853$$

$$= 0.0215 \ g$$

When the same procedure was repeated for other kind of methyl ester, the results as shown in table B.2 was obtained.

Table B.2 GC data of product from tranesterification using commercial ZnO catalyst

Methyl Esters	GC. Area	C_{SD}	Mass of methyl esters(g)*
Methyl Palmitate	1.2278	1.0124	0.0215
Methyl Stearate	0.1209	1.0032	0.0021
Methyl Oleate	3.2678	0.9206	0.0513
Methyl Linoleate	5.4769	0.9787	0.0917
Methyl Linolenate	0.3653	1.0688	0.0068
		Total	0.1734

* based on 1.2022 g of biodiesel product

- To calculation % methyl ester content from the biodiesel product 1.2022 g

From Equation B3,

$$\%ME\ content = \frac{0.1734}{1.2022} \times 100$$

$$= 16.81\ \%$$

Table B.3 Raw Data of ZnO Synthesis by Solvothermal Catalysts for Transesterification

Catalyst	Weigh (g)				M.E.Content, %by wt.
	Oil	MeOH	Catalyst	M.E.after	
ZnO Commercial	10.0017	3.3012	0.3007	5.5385	13.9121
ZnO Solvothermal	10.0014	3.3014	0.3002	5.4901	16.8131
30% K_2CO_3 /ZnO Solvothermal	10.0012	3.3004	0.3002	7.0193	80.6618

Table B.4 Raw Data of Heterogeneous Catalysts for Transesterification

Metal on ZnO	% load	Weigh (g)				M.E. Content, %by wt.
		Oil	MeOH	Catalyst	M.E. after	
Li_2CO_3	15	10.0013	3.3024	0.3003	6.1343	35.2645
	20	10.0021	3.3022	0.3002	6.2475	36.7696
	25	10.0015	3.3032	0.3005	6.3323	39.3047
	30	10.0021	3.3012	0.3004	6.3856	42.1072
Na_2CO_3	15	10.0023	3.3044	0.3009	6.0518	29.2488
	20	10.0018	3.3024	0.3005	6.1208	31.2180
	25	10.0015	3.3011	0.3003	6.1834	35.0123
	30	10.0014	3.3009	0.3005	6.1766	48.1095
K_2CO_3	15	10.0013	3.3021	0.3001	7.6917	60.0400
	20	10.0012	3.3007	0.3008	7.7802	63.7940
	25	10.0021	3.3004	0.3001	7.8244	70.1849
	30	10.0011	3.3009	0.3006	7.8978	77.4774
KOH	15	10.0015	3.3011	0.3004	7.5523	47.1498
	20	10.0017	3.3012	0.3007	7.6385	49.6680
	25	10.0014	3.3014	0.3002	7.6901	51.6791
	30	10.0012	3.3009	0.3004	7.7125	68.6922
KCl	15	10.0012	3.3004	0.3002	5.0193	11.4486
	20	10.0011	3.3002	0.3006	5.0794	12.2375
	25	10.0002	3.3008	0.3005	5.1183	14.2807
	30	10.0011	3.3011	0.3002	5.1428	15.8424
KNO_3	15	10.0008	3.3007	0.3006	6.4204	27.7106
	20	10.0002	3.3012	0.3001	6.4894	28.9027
	25	10.0011	3.3011	0.3002	6.4649	30.4535
	30	10.0007	3.3014	0.3004	6.4207	38.1746

Table B.5 Raw Data of Effect of Parameters on Transesterification

Parameters	Conditions	Weigh (g)				M.E.Content, %by wt
		Oil	MeOH	Catalyst	M.E. after	
Amount of catalyst (%wt. of oil)	1	10.0013	3.3007	0.1002	7.8638	19.5249
	3	10.0011	3.3009	0.3006	7.8978	77.4774
	6	10.0009	3.3011	0.6007	7.4204	75.8718
	9	10.0006	3.3014	0.9004	7.3894	75.6063
Oil to Methanol Molar Ratio	1: 3	10.0012	1.1005	0.3007	7.0193	22.3217
	1: 6	10.0007	2.2003	0.3002	7.1794	37.8239
	1: 9	10.0011	3.3009	0.3006	7.8978	77.4774
	1: 12	10.0005	4.4002	0.3004	7.8983	76.5761
Reaction Time (hr)	6	10.0002	3.3008	0.3005	7.6183	14.4869
	12	10.0012	3.3009	0.3004	7.7125	24.8384
	24	10.0018	3.3024	0.3005	7.6808	31.7966
	36	10.0015	3.3011	0.3003	7.7834	69.2622
	48	10.0011	3.3009	0.3006	7.8978	77.4774
	60	10.0013	3.3024	0.3003	7.8343	77.3614
	72	10.0021	3.3022	0.3002	7.8475	77.6301

Table B.6 Raw Data of Heterogeneous Reused Catalysts for Transesterification

Metal on ZnO	Conditions	Weigh (g)				M.E.Content, %by wt.
		Oil	MeOH	Catalyst	M.E.after	
30% Li_2CO_3	Reused	10.0014	3.3014	0.3002	6.4901	26.8493
30% Na_2CO_3	Reused	10.0012	3.3009	0.3004	6.5125	32.1576
30% K_2CO_3	Reused	10.0012	3.3004	0.3002	6.0193	34.4616
30% KOH	Reused	10.0011	3.3002	0.3006	6.0794	31.4408
30% KCl	Reused	10.0002	3.3008	0.3005	6.0183	11.9966
30% KNO_3	Reused	10.0011	3.3011	0.3002	6.0428	26.4231
30% K_2CO_3	Reused-2	10.0008	3.3007	0.3006	6.4204	19.5505
30% K_2CO_3	Non-THF	10.0012	3.3004	0.3002	6.0193	54.3670

Table B.7 Raw Data of Heterogeneous Catalysts for Gas Chromatography

Metal	%load	GC. Area							Total of M.E.(g)
		solvent	in-SD.	Methyl Palmitate	Methyl Stearate	Methyl Oleate	Methyl Linoleate	Methyl Linolenate	
Li_2CO_3	15	112.2354	5.1267	1.5327	0.3296	3.9856	18.5643	0.7724	0.3808
	20	112.4546	5.1309	1.5792	0.3268	3.9247	18.6429	0.7882	0.3858
	25	113.0122	5.1345	1.8582	0.4318	4.8384	21.5908	0.7504	0.4460
	30	112.4567	5.1445	1.9632	0.4534	6.8074	24.1832	0.7707	0.5190
Na_2CO_3	15	112.3489	5.1165	1.3689	0.2688	3.2234	18.1287	0.9836	0.3700
	20	112.3667	5.1233	1.2434	0.2536	2.2874	18.9457	0.9745	0.3761
	25	112.5422	5.1376	1.3984	0.2896	3.4763	18.2673	0.8772	0.3871
	30	113.0746	5.1178	1.9802	0.4624	8.9863	24.5409	0.9507	0.5538
K_2CO_3	15	113.0134	5.0975	4.9867	1.0023	12.9235	26.8805	1.3362	0.7039
	20	112.7592	5.0789	4.9908	1.1427	12.9504	27.2867	1.3247	0.7181
	25	112.6478	5.0883	5.4067	1.1563	12.7628	27.2059	1.3433	0.7264
	30	112.2346	5.0899	5.8657	1.2324	14.6578	29.2041	1.4335	0.7864
KOH	15	112.3469	5.0957	1.7853	0.4012	4.5323	20.5908	0.7204	0.4714
	20	113.0128	5.0878	1.7524	0.4227	4.4834	20.4867	0.7022	0.4968
	25	112.2553	5.0873	1.8954	0.4509	4.8974	22.0908	0.7557	0.5167
	30	112.6268	5.0924	5.4387	1.1385	13.7307	28.3076	1.3408	0.7842
KCl	15	113.1022	5.1762	1.2662	0.1082	3.1484	4.6135	0.3456	0.1379
	20	112.6754	5.1763	1.2783	0.1089	3.1526	4.7024	0.3247	0.1452
	25	112.4432	5.1439	1.2263	0.1093	3.3689	5.4202	0.3542	0.1549
	30	112.9668	5.1456	1.3231	0.1107	3.4011	5.5732	0.3569	0.1634
KNO_3	15	112.9446	5.1287	1.2644	0.2784	2.3152	15.8036	0.7324	0.3310
	20	112.9758	5.1342	1.3224	0.2578	3.1278	15.9457	0.8533	0.3528
	25	112.9985	5.1223	1.4221	0.2996	3.6734	16.6421	0.6834	0.3736
	30	113.0657	5.1262	1.5843	0.3422	3.8834	16.7908	0.6504	0.3982

Table B.8 Raw Data of Effect of Parameters on Transesterification for Gas Chromatography

Parameters	Conditions	GC. Area							Total of M.E.(g)
		Solvent	in-SD.	Methyl Palmitate	Methyl Stearate	Methyl Oleate	Methyl Linoleate	Methyl Linolenate	
Amount of catalyst (%wt.of oil)	1	112.5325	5.2471	1.4425	0.1393	3.5568	8.0934	0.4533	0.1955
	3	112.2346	5.0899	5.8657	1.2324	14.6578	29.2041	1.4335	0.7864
	6	112.2452	5.2261	5.9346	1.2578	14.7547	29.7529	1.5202	0.7618
	9	112.7791	5.2174	6.0164	1.2954	14.6894	30.0502	1.5004	0.7780
Oil to Methanol Molar Ratio	1: 3	112.4386	5.1369	1.5344	0.1784	3.0552	8.8237	0.4024	0.2289
	1: 6	112.7694	5.1573	1.5231	0.3606	3.6347	16.2045	0.6128	0.3784
	1: 9	112.2346	5.0899	5.8657	1.2324	14.6578	29.2041	1.4335	0.7864
	1: 12	112.5623	5.2564	5.9452	1.3267	15.4527	31.0834	1.5423	0.9465
Reaction Time (hr)	6	112.5471	5.1754	1.2365	0.1283	3.3604	5.5525	0.3471	0.1480
	12	112.7542	5.1274	1.2004	0.2753	2.3059	14.8643	0.6239	0.2694
	24	112.3405	5.1373	1.4733	0.3054	3.6538	16.4509	0.6243	0.3182
	36	112.5204	5.1435	6.7864	1.1567	13.5437	27.9324	1.4034	0.7223
	48	112.2346	5.0899	5.8657	1.2324	14.6578	29.2041	1.4335	0.7864
	60	112.4704	5.1595	6.0853	1.3857	15.0742	30.2473	1.4653	0.8067
	72	112.3524	5.1343	6.9974	1.3562	16.6357	31.7483	1.7539	0.9240

Table B.9 Raw Data of ZnO Synthesis by Solvothermal Catalysts for Gas Chromatography

Catalyst	GC. Area							Total of M.E.(g)
	Solvent	in-SD.	Methyl Palmitate	Methyl Stearate	Methyl Oleate	Methyl Linoleate	Methyl Linolenate	
ZnO Commercial	112.4299	5.1624	1.2278	0.1209	3.2678	5.4769	0.3653	0.1673
ZnO Solvothermal	112.4075	5.1346	1.2432	0.1211	3.2545	5.4724	0.3709	0.1734
30% K_2CO_3 /ZnO Solvothermal	113.1145	5.2135	7.7224	1.6085	18.8538	33.7991	1.7965	1.0275

Table B.10 Raw Data of Heterogeneous Reused Catalysts for Gas Chromatography

Metal on ZnO	Conditions	GC. Area							Total of M.E.(g)
		Solvent	in-SD.	Methyl Palmitate	Methyl Stearate	Methyl Oleate	Methyl Linoleate	Methyl Linolenate	
30% Li_2CO_3	Reused	112.3467	5.1674	1.2689	0.1808	3.1264	15.1287	0.8736	0.3275
30% Na_2CO_3	Reused	112.5426	5.0934	1.2744	0.1859	3.1604	15.1342	0.8806	0.3279
30% K_2CO_3	Reused	112.2468	5.1224	1.3689	0.2688	3.2234	17.1287	0.9836	0.3482
30% KOH	Reused	112.3572	5.1074	1.2876	0.1973	3.2004	15.1899	0.8832	0.3157
30% KCl	Reused	112.4336	5.1344	1.2662	0.1872	2.0484	5.1135	0.1456	0.1435
30% KNO_3	Reused	112.3579	5.1233	1.1459	0.1448	2.5784	13.1287	0.7959	0.2789
30% K_2CO_3	Reused-2	112.3671	5.1468	1.1247	0.1425	2.0407	10.7659	0.7426	0.2319
30% K_2CO_3	Non-THF	112.2308	5.1244	1.9548	0.4665	8.8709	24.3572	0.9147	0.5446

APPENDIX C

Raw Data for the Characterization of Catalyst

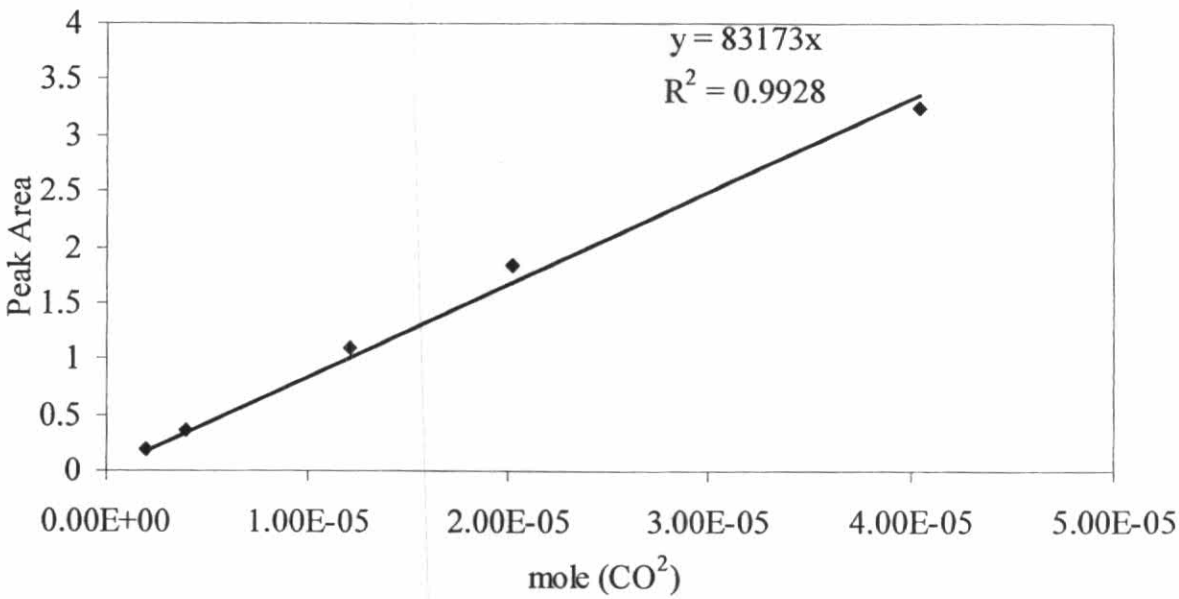

Figure C.1 Calibration curve of CO_2 temperature programmed desorption analysis

Table C.1 Data of CO_2 Temperature Programmed Desorption Analysis

Alkali metal on ZnO	Basicity(μmol/g)			
	15%	20%	25%	30%
Li_2CO_3	11.22	12.19	15.11	18.72
Na_2CO_3	9.25	10.79	10.73	21.72
K_2CO_3	19.27	21.10	22.84	26.59
KOH	11.36	13.00	15.88	25.73
KCl	0.64	0.88	1.97	3.65
KNO_3	11.49	11.85	13.09	13.71
K_2CO_3 (solvothermal)	27.42	28.77	33.77	37.64

Table C.2 Raw Data of Scanning Electron Microscope Analysis

Metal salt	Percent Loaded(w/w)	Surface Area (m^2/g)	Pore Volume (cm^3/g)	Pore Size (Å)
ZnO commercial	-	4.7166	0.0185	157.14
ZnO solvothermal	-	7.6302	0.0225	117.70
K_2CO_3 non cal	30%	0.3349	0.0038	452.53
Li_2CO_3	15%	1.6495	0.0049	119.80
	20%	1.4166	0.0049	138.07
	25%	1.4586	0.0054	148.50
	30%	1.3350	0.0046	136.41
Na_2CO_3	15%	3.3835	0.0108	127.35
	20%	3.1387	0.0058	73.65
	25%	3.1910	0.0067	83.51
	30%	1.8010	0.0062	137.17
K_2CO_3	15%	3.0855	0.0061	79.72
	20%	2.7200	0.0071	103.94
	25%	2.1802	0.0060	110.89
	30%	1.7485	0.0047	106.75
KOH	15%	3.1918	0.0109	137.16
	20%	3.1726	0.0110	139.94
	25%	2.9667	0.0099	134.05
	30%	1.3895	0.0079	227.29
KCl	15%	3.8377	0.0085	88.34
	20%	3.7934	0.0078	82.05
	25%	2.6753	0.0076	113.90
	30%	2.6422	0.0070	106.29
KNO_3	15%	1.6074	0.0019	46.47
	20%	1.4651	0.0018	48.61
	25%	0.9016	0.0031	136.99
	30%	0.5195	0.0020	156.48

Table C.3 Raw Data of X-ray Photoelectron Spectroscopy Analysis

XPS	Peak	Position BE(eV)	FWHM (eV)	Raw Area(CPS)	RSF	Atomic Mass	Atomic Conc%	Mass Conc%
30%Li2CO3/ZnO	Zn 2p	1022	1.965	20376.7	27.3	65.387	5.83	23.41
	O 1s	532	3.444	11672.1	2.85	15.999	31.99	31.43
	C 1s	285	1.892	7679.7	1	12.011	59.99	44.24
	Li 1s	58.6	0.458	16.8	6.942	2.18	2.18	0.93
30%Na2CO3/ZnO	Zn 2p	1021.9	1.997	27163.3	27.3	65.387	12.68	40.45
	O 1s	531.8	3.347	8609.4	2.85	15.999	38.49	30.05
	C 1s	285	1.838	3703.5	1	12.011	47.19	27.66
	Na 2s	63	0.984	50.4	0.39	22.99	1.65	1.85
30%K_2CO_3/ZnO	Zn 2p	1021.9	2.12	19335.6	27.3	65.387	7.99	25.34
	O 1s	531.6	3.258	8446	2.85	15.999	33.44	25.94
	K 2p	285	1.917	3986	4.04	39.102	11.13	21.11
	C 1s	285	1.952	4203.4	1	12.011	47.43	27.62
30%K_2CO_3/ZnO non calcined	Zn 2p	1022	2.198	13761.3	27.3	65.387	3.31	11.68
	O 1s	532	2.924	13503.9	2.85	15.999	31.15	26.81
	K 2p	284.9	2.112	7993.8	4.04	39.102	13.01	27.42
	C 1s	285	2.117	7991.3	1	12.011	52.53	34.02
30%KOH/ZnO	Zn 2p	1022.4	2.388	17617.4	27.3	65.387	7.48	23.98
	O 1s	532	2.769	10341.3	2.85	15.999	42.05	32.99
	K 2p	285.4	2.761	3490.5	4.04	39.102	10.01	19.2
	C 1s	285	2.642	3492.1	1	12.011	46.46	23.83
30%KCl/ZnO	Zn 2p	1022.1	1.984	28318.9	27.3	65.387	10.23	29.93
	K 2p	285	1.817	7208.3	4.04	39.102	17.59	30.79
	C 1s	285	1.812	7273.4	1	12.011	71.72	38.55
	Cl 2p	200.3	1.031	110.1	2.36	35.46	0.46	0.73
30%KNO_3/ZnO	Zn 2p	1021.9	1.948	21204.6	27.3	65.387	8.17	25.75
	O 1s	531.9	3.421	9429.2	2.85	15.999	34.81	26.84
	N 1s	406.7	0.718	74.4	1.77	14.007	0.44	0.3
	K 2p	285	1.917	4222.9	4.04	39.102	11	20.72
	C 1s	285	2.004	4332.6	1	12.011	45.58	26.39

VITA

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