Production of Biodiesel from Triglycerides Transesterification by Alkali Solid Catalysts

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Abstract: This study developed low-cost alkaline granular catalysts for transesterification of triglycerides to produce biodiesel. We found using calcium acetate as a solid catalyst source is better than calcium carbonate. And the best calcination condition is 800ºC, 2 hours. The prepared catalyst achieved the highest of 97.86% biodiesel yield under the reaction conditions of : temperature of 65ºC, catalyst loading 47% and M/O 11.5/1 in 7h, thus it can become a promising commercial transesterification catalyst.

Keywords: Alkali Solid Catalysts, Biodiesel, Transesterification.

1. Introduction

Biodiesel is a mixture with physical properties and boiling point similar to diesel and thus can be mixed with diesel at different ratios to use as fuel for bus, airplane or other transportation vehicles. Biodiesel is currently produced from transesterification of material containing triglyceride with methanol by homogeneous alkali catalyst such as NaOH or KOH. In this study, we tried to develop a low-cost and high-performance CaO-based solid alkali catalyst to replace the homogeneous catalyst and thus to reduce the cost of downstream separation and wastewater treatment.

2. Experimental

Catalyst Preparation:

The catalyst ingredients containing calcium source (calcium carbonate or calcium acetate), bentonite, silicon dioxide, alumina, magnesium oxide and deionized water were well mixed and injected into pellets by syringe. After air drying overnight, the catalyst pellets were calcined in an oven at different temperatures for different time durations and then stored in soybean oil or methanol to prevent activity loss. The XRD pattern of the freshly calcined catalyst pellet was measured and compared with the XRD pattern database to confirm that calcium carbonate or calcium acetate was oxidized to calcium oxide.

Transesterification experiment:

The reactants containing soybean oil, methanol, and catalyst with desired methanol to oil molar ratio and catalyst to oil weight ratio were placed in aluminum reactors. Several reactors containing reactants with different ratios were locked to a metal plate with controllable rotating speed in a temperature-controlled chamber. After the chamber temperature (65 ^{0}C), plate rotating speed (200 rpm), and reaction time (7 h) were set, the reaction was started. When the reaction was complete, the reactors was taken out and placed in an ice bath immediately to quench the reaction. The cooled down reaction mixture in each reactor was separated into two phases and the fatty acid methyl ester content of the oil phase was analyzed by a GCMS (Shimadzu, model: QP2020). The biodiesel production rates of different reaction conditions, calculated from the fatty acid methyl ester purity in the oil phase and the oil phase weight were compared.

3. Results and discussion

The experimental results are summarized in Table 1.

Table 1. Summary of transesterification tests

	Catalyst composition						Calcination condition		Reaction condition					BD production rate
cat No.	$CaCO_3$, g	bentonite, g	SiO_2, g	Al_2O_3, g	$Ca(C_2H_5COO)_2$, g	MgO, g	T, °C	time, h	storage	cat. wt, g	Oil wt, g	MeOH wt, g	mole ratio	g BD/h/gcat
1	41.2%	52.9%	3.9%	2.0%			850	4	oil	12.65	20.00	10.97	1:15	0.1755
2	44.0%	48.0%	2.0%	6.0%			850	4	oil	12.19	20.01	10.93	1:15	0.1799
3	44.0%	48.0%	2.0%	6.0%			850	4	oil	12.17	20.08	10.98	1:15	0.1844
4	44.0%	48.0%	2.0%	6.0%			850	4	oil	12.17	20.04	10.94	1:15	0.2498
5	32.0%	56.0%	2.0%	10.0%			850	4	oil	9.30	20.01	10.95	1:15	0.2332
6	32.0%	56.0%	2.0%	10.0%			850	4	oil	16.99	20.00	10.94	1:15	0.1300
7	56.3%	43.8%	0.0%	0.0%			850	4	oil	12.52	20.00	10.92	1:15	0.1598
8	40.4%	43.9%	1.8%	14.0%			850	4	oil	13.30	20.00	10.98	1:15	0.1502
9	38.0%	52.0%	10.0%	0.0%			850	4	oil	7.85	20.02	10.94	1:15	0.2506
10	38.0%	52.0%	10.0%	0.0%			850	4	oil	7.69	20.01	10.94	1:15	0.4606
11	35.2%	61.5%	2.2%	1.1%			850	4	oil	8.51	20.02	10.93	1:15	0.2294
12	35.2%	61.5%	2.2%	1.1%			850	4	oil	15.33	20.02	10.94	1:15	0.1506
13	43.4%	47.2%	1.9%	7.6%			850	4	oil	12.58	20.01	10.93	1:15	0.1540
14	41.8%	45.5%	1.8%	10.9%			850	4	oil	12.86	20.00	11.08	1:15	0.1478
15	43.1%	54.9%	2.0%	0.0%			850	4	oil	6.92	20.02	10.92	1:15	0.2651
16	54.0%	38.0%	4.0%	4.0%			850	4	oil	9.98	20.00	10.97	1:15	0.1822
17	40.0%	56.0%	4.0%	0.0%			850	4	oil	7.51	20.00	10.95	1:15	0.2321
18	51.9%	40.4%	0.0%	7.7%			850	4	oil	12.56	20.04	10.92	1:15	0.1237
19	43.8%	56.3%	0.0%	0.0%			850	4	oil	12.28	20.05	10.93	1:15	0.1895
20	40.4%	51.9%	0.0%	7.7%			850	4	oil	13.30	20.02	10.96	1:15	0.1730
21	54.0%	38.0%	4.0%	4.0%			850	4	oil	9.92	20.00	10.99	1:15	0.2225
22		44.0%	2.0%	3.0%	48.0%	3.0%	850	4	oil	15.22	32.18	13.06	1:11.5	0.2956
23		44.0%	3.0%	2.0%	50.0%	2.0%	850	4	oil	11.30	20.00	10.92	1:15	0.2236
24		55.0%	2.0%	4.0%	35.0%	4.0%	850	4	oil	16.14	20.00	10.92	1:15	0.1449
25		51.0%	3.0%	1.0%	44.0%	1.0%	850	4	oil	12.84	20.00	10.92	1:15	0.1634
26		49.0%	4.0%	4.0%	36.0%	4.0%	850	4	oil	15.69	20.00	10.92	1:15	0.1324
27		50.0%	2.0%	6.0%	37.0%	6.0%	850	4	oil	15.27	20.00	10.92	1:15	0.1553
28		54.0%	2.0%	10.0%	31.0%	4.0%	850	4	oil	18.22	20.00	10.92	1:15	0.1283
29		50.0%	4.0%	6.0%	37.0%	4.0%	850	4	oil	15.27	20.00	10.92	1:15	0.1795
30		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	oil	4.00	20.02	8.74	1:12	0.4919
31		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	oil	4.00	20.04	10.92	1:15	0.4724
32		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	oil	4.00	20.06	13.11	1:18	0.4599
33		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	methanol	8.00	20.00	15.92	1:22	0.2622
34		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	methanol	8.00	20.00	15.92	1:22	0.2530
35		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	methanol	8.00	20.00	15.92	1:22	0.2430
36		45.4%	1.0%	1.0%	49.5%	3.1%	850	2	methanol	8.00	20.00	15.92	1:22	0.2470
37		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	2.18	1:3	0.6618
38		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	2.91	1:4	0.7482
39		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	3.64	1:5	0.8382
40		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	4.37	1:6	0.8907
41		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	5.10	1:7	0.9193
42		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	5.82	1:8	0.9743
43		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	6.55	1:9	0.8372
44		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	6.55	1:9	0.5064
45		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	7.28	1:10	0.9284
46		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	7.28	1:10	0.8974
47		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	8.01	1:11	0.9776
48		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	8.74	1:12	0.9971
49		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	9.46	1:13	0.9586
50		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	10.19	1:14	0.9118
51		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	2.00	20.00	10.92	1:15	0.7249
52		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	oil	5.00	20.00	10.92	1:15	0.0333
53		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	methanol	5.00	20.00	10.92	1:15	0.3660
54		41.0%	13.0%	0.0%	38.0%		850	4	methanol	5.00	20.00	10.92	1:15	0.3894
55		41.0%	13.0%	0.0%	38.0%		850	4	methanol	5.00	20.00	10.92	1:15	0.4274
56		41.0%	13.0%	0.0%	38.0%		850	4	methanol	5.00	20.00	10.92	1:15	0.4067
57		41.0%	13.0%	0.0%	38.0%		850	2	methanol	5.00	20.00	10.92	1:15	0.4094
58		41.0%	13.0%	0.0%	38.0%		850	2	methanol	5.00	20.00	10.92	1:15	0.4393
59		41.0%	13.0%	0.0%	38.0%		850	2	methanol	5.00	20.00	10.92	1:15	0.4264
60		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	methanol	5.00	20.00	10.92	1:15	0.4195
61		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	methanol	5.00	20.00	10.92	1:15	0.4048
62		45.4%	1.0%	1.0%	49.5%	3.1%	850	4	methanol	5.00	20.00	10.92	1:15	0.3888
63		45.4%	1.0%	1.0%	49.5%	3.1%	800	2	methanol	4.00	20.00	6.55	1:9	0.5036

4. Conclusions

The catalysts with calcium source from calcium acetate give higher biodiesel production rates than those from calcium carbonate (0.51 vs. 0.20 gBD/h/g cat). For the catalysts with calcium acetate source, stored in methanol give higher biodiesel production rate than stored in oil (0.61 vs. 0.24), calcined at 800 ^{0}C give higher rates than at 850 ^{0}C (0.83 vs. 0.31), calcined for 2h give higher rates than for 4 h (0.74 vs 0.29).