Synthesis of Bulk Calcium Oxide (Cao) Catalyst and its Efficacy for Biodiesel Production

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Abstract: The numerous limitations of the conventional homogenous catalysts have become a great challenge for researchers in the area of biodiesel. Therefore, alternative catalysts for clean and environmental benign process is the solution. Calcium oxide catalyst was prepared from hydrated lime and it was used to produce biodiesel to test its efficacy. It was used to catalyze transesterification of *Jatropha curcas* oil and methanol at 60^0C reaction temperature for 50, 60, 70, 80 and 90 minutes reaction times and the corresponding biodiesel yield of 94.76%, 98.67, 100.00, 89.92 and 99.08% were obtained. The components of methyl ester found in the five samples of the biodiesel are listed.

Key words: synthesis, calcium oxide, catalyst, biodiesel, production

1.INTRODUCTION

Development of heterogeneous catalysts has been a relatively recent area of research in the synthesis of biodiesel. The need for development of heterogeneous catalysts has risen from the fact that homogeneous catalysts used for biodiesel production pose some limitations. These drawbacks include; washing of products with water to remove catalyst from the products which results in waste water generation and loss of biodiesel as a result of washing, the use of intensive biodiesel separation protocol, the corrosive nature of the catalysts and impossibility of catalyst reuse (Edgar et al, Pdf file Retrieved 13/08/2011). Heterogeneous catalysts have the advantages of easy separation from the product, reusability and eco-friendly.

Heterogeneous catalysts are classified into solid base and solid acid. Solid base catalysts comprise of alkaline earth metal oxides, hydrotalcites/layered double hydroxides, alumina loaded with various compounds and zeolites (Sharma and Bhaskar, 2011). Calcium oxide (CaO) is one of the well-researched heterogeneous catalysts as it has a higher basicity, lower price, non-corrosive, economically benign, lower solubility and easier to handle than homogenous base catalysts (Wan Isahak et al, 2010). These advantages together with it being safe to the ecosystem made it an interesting choice in the catalysts research.

A lot of research works have been done on biodiesel with homogenous catalysts in National Research Institute for Chemical Technology NARICT, Zaria, but not much has been done with heterogeneous catalysts. In this paper, calcium oxide catalyst was prepared from hydrated lime locally produced by the division of pilot plant of the National Research Institute for Chemical Technology NARICT, Zaria from lime stone. This catalyst was tested for its catalytic action by producing biodiesel from *Jatropha curcas* seed oil with methanol.

2.MATERIAL AND METHOD

The materials used in this investigation include; an oven for drying the sample, a furnace for firing the catalyst and ceramic crucibles. A top loading balance, conical flasks, magnetic stirrer, hot plate, thermometer and separating funnel for separating biodiesel from glycerol. The reagents used include, analytical grade methanol for transesterification, propan-2-ol and 0.1M potassium hydroxide for determination of FFA of the oils.

2.1 Preparation of Calcium oxide Catalyst

A bag weight of 50 kg hydrated lime was collected from Pilot plant division of National Research Institute of Chemical Technology, Zaria. 200 g of the hydrated lime was dried in an oven to a constant weight. The calcium oxide obtained was calcined in a furnace at 900^0C for 90 minutes at 50% power rate. The possible reaction during the drying is presented below;

$$Ca(OH)_2 \rightarrow CaO + H_2O$$

2.2 Transesterification

100 g of *Jatropha curcas* oil was transesterified with 20 g methanol (mole ratio of 1:5.5) and 1.5 g (1.5% mass of the oil) of the synthesized bulk calcium oxide catalyst at 60^0C for 50, 60, 70, 80 and 90 minutes. The oil was first heated to 60^0C in a conical flask and then, the calcium oxide and methanol mixture were poured into the hot oil. A magnetic stirrer was put into the reaction mixture to stir the reactants. The reaction temperature was maintained at 60^0C throughout the reaction period.

2.3 Separation

At each end of the reaction time the product was filtered and transferred into the separating funnel and left for an hour or more to allow separation of biodiesel and glycerol. These products were collected separately for analysis.

2.4 Ester Test

A quick test which is also called "ester test" was performed on each of the biodiesel produced by dissolving 10 ml of biodiesel into 40 ml of methanol and shacked vigorously.

2.5 GC-MS Analysis

Biodiesel sample from each batch was analyzed with GC-MS in the instrumentation Division of National Research Institute for Chemical Research, Zaria.

3.0 RESULTS AND DISCUSSIONS

All the five biodiesel samples produced dissolved completely in the methanol, this confirmed that the transesterification reactions were complete. The GC-MS analytical results are shown in table 1 below. The results in the table shows an increase in the yield of biodiesel from 50 minutes to 70 minutes but a decrease at 80 minutes and a rise again at 90 minutes. 94.76% at 50 minutes, 98.67% at 60 minutes, 100%, at 70 minutes, 89.92% at 80 minutes and 99% at 90 minutes indicate that the catalyst a good enough for biodiesel production from *Jatropha curas* oil. It is interesting to note that only three methyl esters are common products to all the samples of biodiesel; Methyl hexadecanoate, Methyl 14-methylpentadecanoate and Methyl octadecanoate. This indicates that using the same feed stock, different methyl esters can be produced with different reaction times.

The maximum yield of biodiesel 100.00% at 60^0C for 70 minutes using CaO is higher than that obtained using NaOH homogenous catalyst of 98.6% (Nakpong and Wootthikankklan, 2010) at the optimum reaction conditions of 60^0C temperature, 40 minutes reaction time, 1% w/w catalyst to weight of oil and methanol to oil mole ratio of 6:1. Thus, compare the cost of the two catalysts, production processes, hazardous nature and separation protocol, CaO catalyst is far better than the conventional NaOH homogenous catalyst.

4. CONCLUSION

Higher yield of biodiesel can be obtained with the use of heterogeneous catalyst than the conventional homogenous ones. The use of heterogeneous rather than homogenous catalysts for biodiesel synthesis should impact the cost of producing biodiesel, providing a more environmentally benign process to produce biodiesel with minimal number of process equipment, provide job opportunities and strengthens our economy. Easy recovery of the heterogeneous catalysts from the products and ability to be reused further increase their benefits for transesterification application over homogenous catalysts which are difficult to separate from the product and not reuse. Different compositions of methyl ester can be produced at different reaction times.

5. ACKNOWLEDGEMENT

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Table 1: Components of methyl esters in the biodiesel samples

Methyl ester composition	MF	50” %	60” %	70” %	80” %	90” %
Methyl 10-undecenoate	$C_{12}H_{22}O_2$		0.632			0.188
Methyl tridecanoate	$C_{14}H_{28}O_2$					0.114
Methyl mysristate	$C_{15}H_{30}O_2$					0.362
Methyl palmitoleate	$C_{17}H_{32}O_2$		0.224			1.800
Methyl -7-hexadecenoate	$C_{17}H_{32}O_2$		0.112			0.900
Methyl hexadecanoate	$C_{17}H_{34}O_2$	6.088	8.544	5.892	7.764	11.032
Methyl 14-methylpentadecanoate	$C_{17}H_{34}O_2$	7.130	8.544	5.892	5.676	2.758
Methyl heptadecanoate	$C_{18}H_{3}6O_2$					0.412
Methyl 8-(2-hexylcyclopropyl)ocatanoate	$C_{18}H_{34}O_2$		0.112			
Methyl isoheptadecanoate	$C_{18}H_{36}O_2$		4.272			
Methyl 15-methylhexadecanoate	$C_{18}H_{36}O_2$	4.464		4.142	1.048	
Methyl oleate	$C_{19}H_{36}O_2$	12.688		31.716	7.188	0.900
Methyl octadecanoate	$C_{19}H_{38}O_2$	4.260	7.720	4.784	4.192	11.392
Methyl -7-octadecenoate	$C_{19}H_{36}O_2$			15.858	7.188	12.940
Methyl -9-octadecenoate	$C_{19}H_{36}O_2$				14.376	
Methyl linoleate	$C_{19}H_{36}O_2$		26.588		17.752	
Methyl-8,11-0ctadecadienote	$C_{19}H_{36}O_2$		13.294		8.876	
Methyl-10,13-0ctadecadienote	$C_{19}H_{36}O_2$		13.294			
Methyl-9,11-0ctadecadienote	$C_{19}H_{36}O_2$				8.876	
Methyl-9,12-0ctadecadienote	$C_{19}H_{36}O_2$		13.294			
Methyl 7-octadecenoate	$C_{19}H_{36}O_2$	12.688				
Methyl 8-octadecenoate	$C_{19}H_{36}O_2$	12.688		15.858	7.188	25.880
Methyl olaidate	$C_{19}H_{36}O_2$		0.112			25.880
Methyl -6-octadecenoate	$C_{19}H_{36}O_2$	26.068		15.858		
Methyl 16-methylheptadecanoate	$C_{19}H_{38}O_2$		1.930			2.848
Methyl hydrosterculate	$C_{20}H_{38}O_2$					0.900
Methyl eicosanoate	$C_{21}H_{42}O_2$					0.412
Total		94.76	98.67	100.00	89.92	99.08

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