Kinetics of Transesterification on Jatropha Curcas Oil to Biodiesel Fuel

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Abstract

Biodiesel is one of the many alternative fuel options that can help in reducing oil dependence. It is derived from vegetable oil or animal fats that can be an additive to or entirely replace conventional Petroleum diesel fuel. Transesterification reaction of Jatropha curcas oil with butanol was investigated by using of alkaline catalyst. An experiment has been carried out in the batch-type reaction vessel preheated at 75^0C to 90 ^{0}C and at atmospheric pressure, and with a molar ratio of 1: 21 of the Jatropha curcas oil to butanol. It was consequently demonstrated that, in a preheating temperature of 75-90^0C, 240 s of treatment of butanol was sufficient to convert the Jatropha curcas oil to butyl esters by 25% (weight) and that, the prepared butyl esters (BE) yield was found to be higher in alkali based than that by acid based transesterification. In addition, it was found that this reaction temperature of 105 ^{0}C was considered as the best condition, with the molar ratio of butanol to Jatropha curcas oil being 11.

Key Words: Transesterification, Jatropha Curcas Oil, Biodiesel.

I. INTRODUCTION

The search for environmentally friendly materials that have potential to substitute mineral oil in various industrial applications is currently being considered a top priority research topic in the fuel and energy sector. This emphasis is largely due to the rapid depletion of world fossil fuel reserves and increasing concern for environmental pollution from study, kinetics of transesterification of non edible Jatropha curcas oil to biodiesel fuel was treated in batch reactor with butanol by using of NaOH catalyst. We reported the effects of molar ratio and reaction temperature on butyl ester formation followed by a proposed simple method for the kinetics of the transesterification reaction.

excessive mineral oil use and their disposal. Jatropha Curcas is the promising raw material for the biodiesel in context of India. Biodiesel production from vegetable oils takes place through different chemical reactions, but transesterification of vegetable oils with simple alcohol has long been a preferred method for producing biodiesel fuel. Generally speaking, there are two methods of transesterification reaction. One is the method using a alkali catalyst and the other is with the help of a acid catalyst. Alkali catalyzed reactions are preferred to the later due to formation of water.

Recently, uncatalyzed transesterification of rapeseed oil in supercritical methanol as recently reported by Saka and Kusdiana.. Noureddin and Zhu applied the effects of mixing of soybean oil with methanol on its kinetics of transesterification. Diasakov reported kinetics on uncatalytic transesterification reaction of soybean oil. Weiliang Cao studied the transesterification of soybean oil in supercritical methanol has been carried out in the absence of catalyst but with a co-solvent was added to the reaction mixture in order to decrease the operating temperature, pressure and molar ratio of alcohol to vegetable oil.
However, the kinetic study of non edible vegetable oil in with and without catalyst has not yet been presented. Therefore, in this Study, kinetics of transesterification of non edible Jatropha curcas oil to biodiesel fuel was treated in batch reactor with butanol by using of NaOH catalyst. We reported the effects of molar ratio and reaction temperature on butyl ester formation followed by a proposed simple method for the kinetics of the transesterfication reaction

II EXPERIMENTAL

A. Materials

Jatropha Curcas oil from National Biofuel Corporation, New Delhi was used as the raw oil. The fatty acid composition was determined by Gas chromatography for removal of free fatty

acid. Butanol was purchased from SRL Chemical Ltd and Sodium hydroxide was purchased from Nice Chemical.

B. Batch transesterification method for Jatropha Curcas

The batch transesterification reaction system employed in this work is shown in Fig. 1. A 1500 ml glass reactor equipped with mechanical stirrer, thermometer, condensing coil and sample port was used in all kinetic experiments. The reactor was immersed in constant temperature heating mental which was capable of controlling the temperature to within deviation of 5^0C .A mechanical stirrer fitted with stainless steel propeller provided the mixing requirement . *Thirty seven reactions* were carried out over the entire duration of experimental work. The conditions such as reactants, temperature, catalyst and mixing intensity, where varied to assess firstly the rate of reaction and secondly the best possible conditions. The Procedure that was used for each reaction is as follows;
The reactor was initially charged with Jatropha oil depending upon the required molar ratio of oil to Butanol. The reactor assembly was then placed in constant heating mental and heated to the desired temperature. Measured amount of the Butanol and sodium hydroxide stock solution, which was heated separately to the reaction temperature, was added to the reactor. Mechanical stirrer was started as per required temperature. The reaction was timed as soon as mechanical stirrer was turned on. .During the experiment

Figure. 1 Batch Transesterification System.

1. Glass Rector .
2. Heating Mental
3 Thermometer
4 Mechanical Stirrer
5. Condenser

run the samples were drawn at 20 minutes of time interval. Approximately 3 to 4 samples were collected during the course of each reaction (60minutes).Samples were collected in 10ml test tubes filled with 4ml of distilled water. The test tubes were kept in an ice bath at about 50^0C prior to use. Samples (2ml) were quenched in the test tubes by placing them in the ice bath immediately after removal from glass reactor. The test tubes were then shaken to stop the reactions. After measuring their residual weight, the upper and the lower portions were analyzed for its composition by using the gas liquid chromatography (GLC) (Nucon GLC which consists of the diameter of column- DB-5 Column, Length 15 meter and Internal diameter .32mm)

III. RESULTS AND DISCUSSION

Assuming that the transesterification reaction of the Jatropha curcas oil with the butanol proceeds under the same reaction mechanism as that of using liquid methanol, the reaction proceeds with any catalyst .Theoretically, transesterification reaction is equilibrium reaction. In this reaction, however, more amount of butanol was used to shift the reaction equilibrium to the right side and produce more butyl esters as the proposed product.

A. Effect of molar ratio of butanol to rapeseed oil

The molar ratio of butanol to Jatropha curcas oil is one of the most important variables affecting the yields of butyl esters converted. The stoichiometry of the transesterification of Jatropha curcas oil requires three molecules of butanol to react with one molecule of Jatropha curcas oil. Conventional commercial process with alkaline catalyst that the yield of esters increases as the molar ratio of alcohol to oil rises and that the optimal ratios for its result 5 to 42. In this work, therefore, the effect of the molar ratio of butanol to Jatropha curcas oil was studied in the range between 6 and 23 on the yield of butyl esters formed batch treatments, assuming that the average molecular weight of Jatropha curcas is 873 as triglycerides. Therefore, from Fig. 2, it is apparent that the conversion state of Jatropha curcas oil is different as various molar ratios of butanol were applied to the transesterification reaction of the J. Curcas oil. With a higher molar ratio of butanol applied, the butyl esterified compounds are increased with a decrease in the intermediate

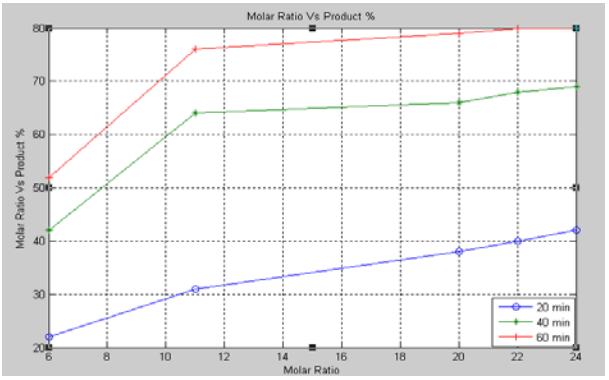

Fig. 1 Product (wt %) and molar ratio. The composition of the butyl ester formation during the transesterification of Jatropha curcas oil at 105^0C and 150 rpm of impeller

The product (wt %) 22, 43, 52 at the time 20, 40 and 60 min respectively for molar ratio 6. On increasing the value of molar ratio from 6 to 20, the butyl ester formation increase in linear function ratio of Butanol. The molar ratio value exceed than 11, become constant function of butyl ester formation. From figure 2 it was clear that transesterification of Jatropha curcas suited with Butanol ratio from 11 to 20. The excess of butanol shift the reaction towards the forward, ease of downstream processing and in kinetic domain region.

B. Effect of temperature on butyl esters formation

To determine the effect of temperature on butyl esters formation, transesterification reactions of Jatropha curcas oil were carried out with molar ratio of 20 in butanol, the best condition found in Fig. 3 , at various temperatures ranging

from 95 to 115^{0}C. Fig. 3 show of Jatropha curcas oil as treated in various conditions of temperatures and reaction times. At temperatures of 95 and 100^{0}C, the relatively higher conversion to butyl esters is evident in Fig. 3. In these conditions, butyl esters formed are at most about 55 and 60% at (1h) treatment. These results are in good accordance with those already reported

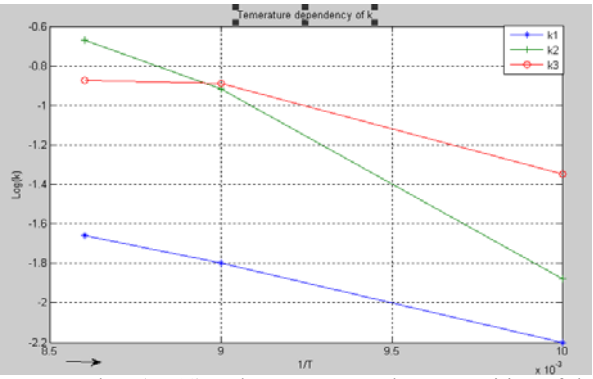

Fig 2 Product (wt %) and temperature. The composition of the butyl ester formation during the transesterification of Jatropha curcas oil at 1:20 molar ratio and 150rpm of impeller

The product formation decrease with increase of the temperature. As the temperature increased from 97^{0}C there was steep fall in product formation up to temperature of 105^0 C. While on further increase of temperature there was exponential rise of product formation. The region above 97^0 C was not suitable to shift the reaction towards the equilibrium. To maintain the reaction in forward direction the value of ester production with respect to temperature should be linear relationship.

C. Temperature dependency of the reaction rate constant

On plotting the tangent on curve on figure 3, the rate of reaction was found by using MAT lab software the matrix of rate of reaction vs. concentration produce the following data seen in table 1.Activation energies were estimated by an expression to the Arrhenius equation

$$K(T)=A\ e^{-E/RT}$$

Table 1 the parameter was fitted as per as Arrhenius equation for activation energy

log K_1	log K_2	log K_2	log K_2
-2.2	-1.18	-1.35	.010
-1.8	-.916	-.889	.009
-1.66	.669	-.84	.0086

This expression, derived from the transitions state theory, shows the temperature dependency of reaction rate constant. For n=0, this relationship reduce to the Arrhenius equation

$$\mathbf{Log\ (K_2/K_1) = E/R\ [1/T_1 - 1/T_2]}$$

On plotting the graph between log (K_2/K_1) and 1/T as seen in Fig 3, the slope was equal

The rate constant value increased with respect to time, which suggests that reaction equilibrium towards right. The average activation energies of Jatropha curcas at 105^{0}C at 30gm of catalyst is 152 KJ/mol.

IV CONCLUSION

We have shown that batch transesterification method is required much lower reaction temperatures and pressures. In addition, because of the optimize amount of sodium hydroxide catalyst, the purification of products after transesterification is much simpler and more environmentally friendly. From experimental run it was found that the average composition of BE 71.88, TG 38, DG 12 and MG 11 (wt% composition) at operating temperature of 105^{0}C , mixing intensity 150 rpm and 1:20 molar ratio of Jatropha curcas to butanol. These relatively mild reaction conditions and high yield of butyl esters using this environmentally friendly method make it viable for practical use in industry.

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