Production of biodiesel fuel from Jatropha curcas oil using potassium zirconate as heterogeneous catalyst

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Abstract— **Synthesis of novel heterogeneous catalysts and their application for transesterification is a convenient and non-toxic way for the production of transportation fuel. Potassium zirconate heterogeneous solid base catalyst was prepared by impregnation and was used as a potential catalyst for the production of biodiesel from Jatropha curcas oil. Influence of main reaction parameters on the reaction yield such as reaction time, methanol to oil molar ration and catalyst weight were studied under various reaction conditions to obtain the maximum yield. The maximum yield of fatty acid methyl esters obtained was 94.19 % for the transesterification reaction over the potassium zirconate catalyst with a catalyst to oil weight percentage of 6 and methanol to oil molar ratio of 12 at 65 °C for 3 hours. The biodiesel produced under the optimum reaction condition was characterized by Fourier transform infrared spectroscopy.**

Keywords- Jatropha curcas; biodiesel; potassium zirconate; FAME yield

I. INTRODUCTION

Transportation sector is in profound search of alternative fuel inorder to replace the conventional fuel due to the fast depletion of fossil fuel resources. Fatty acid alkyl esters which are commonly called biodiesel produced by catalytic transesterification is a better alternative for the conventional transportation fuel [1]. The main sources for the production of biodiesel are vegetable oils and animal fats. Biodiesel has comparable physical and chemical properties as the conventional diesel fuel and biodegradable and eco-friendly [2]. Among the various renewable feedstocks, non-edible vegetable oils can be used as the potential feedstocks since they will not arise any food scarcity or land management issues [3]. Jatropha Curcas is a non-edible plant mainly cultivating in South Africa, South and Central America and South East Asia which can grow with less maintenance cost [4]. Jatropha curcas oil can be directly converted to biodiesel by the process of catalytic transesterification. Transesterification can be performed by following homogeneous catalysis or by heterogeneous catalysis. Homogeneous catalysts involve NaOH, KOH, HCl, and H_2SO_4. Eventhogh homogeneous catalysis produces biodiesel in very high yield; the separation of the catalyst from reaction mixture is very difficult which will produce large amount of waste water [5]. At present the demand goes to heterogeneous solid base catalysts such as supported alkali and alkaline earth metal oxides, hydrotalcites, and bimetallic mixed oxides [6, 7, 8]. In the present study, we have prepared potassium zirconate catalyst by impregnation method for the production of biodiesel from Jatropha curcas oil. Important reaction parameters such as reaction time, catalyst to oil weight ratio and oil to methanol molar ratio were optimized to getter better fatty acid methyl ester (FAME) yield. Biodiesel produced under the optimum reaction conditions was characterized by Fourier transform infrared spectroscopy incorporating the applicable criteria that follow.

II. EXPERIMENTAL

A. *Synthesis of catalyst and characterization*

Potassium zirconate catalyst was prepared by impregnation route. Zirconyl oxynitrate hexahydrate ($ZrO(NO_3)_2.6H_2O$) was dissolved in 100 ml distilled water and stirred well to dissolve completely. Potassium nitrate (KNO_3) was the added to the solution and impregnated to dryness. Potassium to zirconium stoichiometry ratio was kept at 2:1. The sample was then dried for overnight at 90° C and calcined at 900°C. The prepared catalyst was characterized by Fourier transform infrared spectroscopy (FTIR).

B. *Transesterification of Jatropha curcas oil*

In a typical run 10 g of jatropha oil was stirred with catalyst methanol at 65°C. After the completion of reaction, the reaction mixture was centrifuged and the upper fatty acid methyl ester (FAME) layer was separated from the glycerol layer at the bottom. FAME was washed several times with distilled water inorder to remove impurities. Analysis of the biodiesel produced was done using a SRI Gas Chromatograph equipped with MXT ® biodiesel TG column and a flame ionization detector. FAME yield was determined based on the GC data.

III. Results and Discussion

FTIR spectrum of the catalyst is shown in Fig. 1. The bands observed in range 3000-3400 and 1640 cm^{-1} were assigned to the -OH stretching and bending vibrations of absorbed water molecule from atmosphere. The peaks around 1400-1430 cm^{-1} and 1000-950 cm^{-1} could be attributed to the vibrations of K-O-Zr bond. The peaks in the range 900-400 cm^{-1} were due to the characteristic stretching vibrations of metal-oxygen bonds.

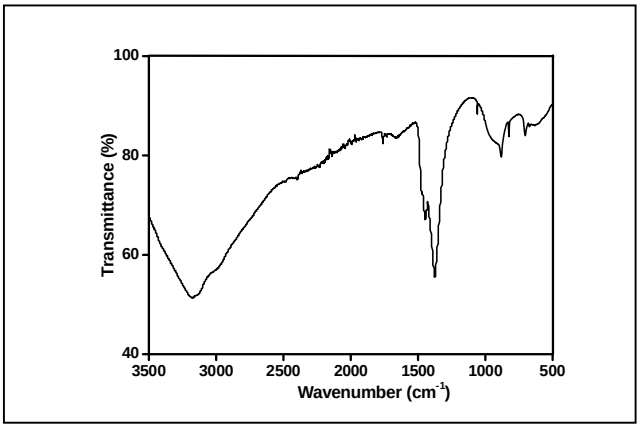

Fig 1. FTIR spectrum of potassium zirconate

Influence of reaction time on the FAME yield was studied by varying the reaction time from 1-6 hours at methanol to oil molar ratio 1:12 and catalyst amount 6 wt% to oil. The results are shown in Fig. 2. The FAME yield was observed to be increased with increase in reaction time and a maximum FAME yield (94.19%) was obtained at 3 h of reaction time.

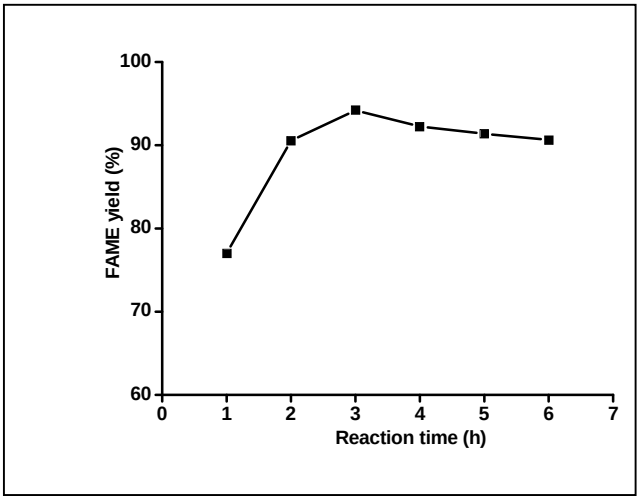

Fig 2. Effect of reaction time on the transesterification of jatropha oil: catalyst amount 6 wt%, methanol/oil molar ratio 12: 1, reaction temperature 65 °C.

Effect of methanol-oil molar ratio on the reaction yield was studied at different methanol molar ratios such as 3, 6, 9, 12, 15 and 18. Fig. 3 shows the effect of methanol to oil molar ratio on the FAME yield. Increase in the ratio of methanol upto 12 showed a considerable increase in the FAME yield beyond which no further increase was observed.

Finally, the effect of catalyst wt% on the FAME yield was investigated by varying the catalyst to oil wt% from 2-10. Results shown in Fig. 4 clearly outlines that an increase in the catalyst wt%, increases the FAME yield. A maximum FAME yield was obtained when the catalyst to oil wt% was 6 and a further increase in the catalyst weight caused a slight decrease in the FAME yield.

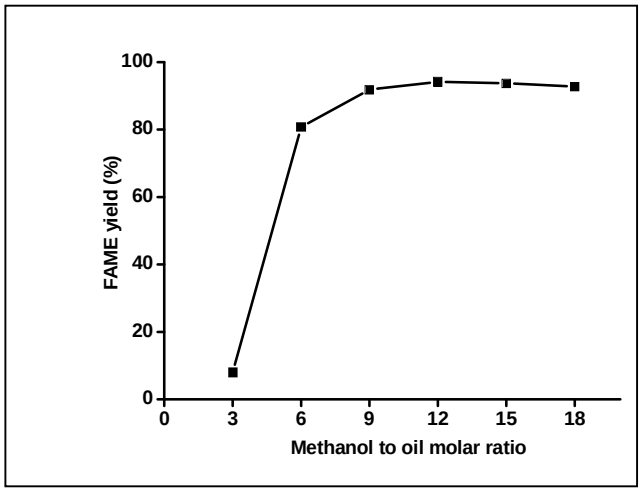

Fig 3 Effect of methanol to oil molar ratio on the transesterification of jatropha oil: catalyst amount 6 wt%, reaction time 3 h, reaction temperature 65 °C.

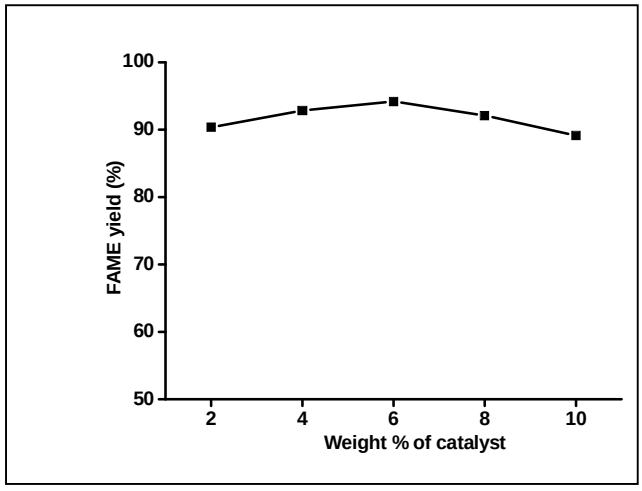

Fig 4. Effect of catalyst to oil weight ratio on the transesterification of jatropha oil: methanol/oil molar ratio 15: 1, reaction time 2 h, reaction temperature 65 °C.

FTIR spectrum of biodiesel is shown in Fig. 5. The peak at 1740 cm^{-1} for biodiesel corresponds to C=O stretching. The peak due to C(=O)-O stretching was observed at 1245 cm^{-1}. The peak corresponds to methylene groups near carbonyl groups appeared at 1171 cm^{-1}. A peak corresponds to the methyl rock ρMe was observed at 1198 cm^{-1} [9]. Table 1. shows a comparative study of activities of catalysts used for the production of biodiesel

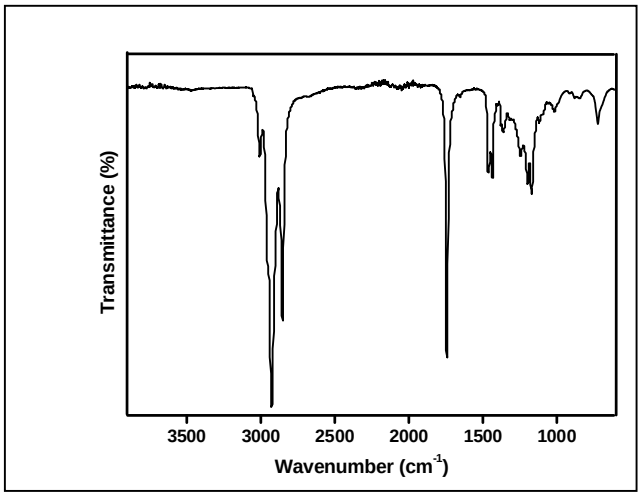

Fig. 5. FTIR spectrum of biodiesel

TABLE I. COMPARISON OF THE CATALYTIC ACTIVITY OF CATALYST USED FOR THE BIODIESEL PRODUCTION

Catalyst	Feedstock	FAME yield (%)	Reference
Bi_2O_3-La_2O_3	*Jatropha curcas* oil	93	[2]
MgO-KOH	Mutton fat	98	[10]
K_2SiO_3/AlS BA-15	*Jatropha curcas* oil	95	[5]
TiO_2-MgO	Waste cooking oil	92.3	[11]
Sr/MgO	Soybean oil	93	[12]
MgO-ZnO	*Jatropha curcas* oil	94	[13]
La_2O_3/ZrO_2	Sunflower oil	84.9	[14]

IV. CONCLUSIONS

Potassium zirconate solid base catalyst was prepared by impregnation method for the catalytic transesterification of jatropha oil. The prepared catalyst showed remarkable activity for the conversion of jatropha oil into biodiesel. Investigation of the effect of reaction parameters such as reaction time, methanol to oil molar ratio and catalyst to oil weight ratio showed that a maximum FAME yield of 94.19% was obtained at catalyst to oil weight percentage 6 and methanol to oil molar ratio 12 and for 3 hours of reaction time.

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