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BIODIESEL PRODUCTION FROM SORGHUM OIL BY TRANSESTERIFICATION USING ZINC OXIDE AS CATALYST

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Abstract

Biodiesel production is worthy of continued study and optimization of production procedures due to its environmentally beneficial attributes and its renewable nature. Heterogeneous transesterification is considered to be a green process. This paper presents the effect of different factors that affect the conversion of sorghum oil to biodiesel and the optimum conditions in a batch reactor using zinc oxide as catalyst. Four replicate transesterification experimental runs were carried out for each of the mixing duration 25, 50, 75, 100 minutes under different typical transesterification reaction condition of 100 ml sorghum oil, temperature (37°C, 57°C, 67°C), zinc oxide concentration (0.25%, 0.5%, 1.0%, 1.5%) (wt % sorghum oil), ethanol to oil ratio (6:1, 8:1, 12:1, and 24:1) at a constant mixing rate. The optimum conditions were found to be 1.0% ZnO, 18:1 ethanol to oil ratio, 67°C temperature and highest yield of biodiesel obtained was 96 %.

Keyword: Sorghum oil; Zinc oxide; Transesterification; Biodiesel.

1. Introduction

The extensive use of fossil fuel in human activities during the last several decades causes the depletion of fossil fuel sources; therefore, the search of other alternative energies is crucially important [1, 2]. Biodiesel is receiving increasing attention as an alternative, non-toxic, bio-degradable, and renewable diesel fuel. One of the alternative fuels which have been developed over a century ago is biodiesel. Biodiesel has been chosen as an alternative fuel because it is renewable, produces lower emission, and possesses high flash point, better lubrication and high cetane number [3].

Studies about the transesterification of vegetable oils or animal fats into biodiesel have been conducted by various researchers. At the time of reaction, the triglycerides will gradually be converted into diglycerides, monoglycerides, and glycerol. At each change of conversion, one mole of ester formed [4]. Different kinds of catalyst have been in use to produce biodiesel from a different kind of oil. The catalyst commonly used for biodiesel production are categorized into several types: homogeneous catalyst (sodium hydroxide, potassium hydroxide, and sulfuric acid) [5], heterogeneous catalysts (carbon-exchange resin, hydrotalcicites, etc), and enzymes (Chromobacterium viscosum, Candida rugosa, Porcine pancreas) [6].

Compared with conventional homogeneous acids, solid acid catalysts have many significant advantages such as less corrosion, less toxicity and less environmental problem [7]. Conventionally, transesterification is performed using homogeneous alkaline catalyst such as NaOH, KOH, or sodium methoxide [8]. While the application of heterogeneous catalysts appears promising because they can simplify the production and purification processes, decrease the amount basic waste water, downsize the process equipment, and reduce the environmental impact and process cost [9]. However, in this conventional homogeneous method, the removal of these catalysts is very difficult, and a large amount of wastewater is produced to separate and clean the catalyst and the products. Therefore, conventional homogeneous catalysts are expected to be replaced by environmentally friendly heterogeneous catalysts. The replacement of homogeneous catalysts by heterogeneous catalysts would have various advantages such as the easy catalyst separation from the reaction mixture, product purification, and the reduction of environment pollutants [10-13].

Sorghum (*Sorghum bicolor*), is a genus that belongs to the Poaceae family with many species in tropical and subtropical countries; eight species are reported to occur in India. Sorghum grain is crop plant, which grown in several parts of India. The food, feed and fodder needs of farmers will not be affected, as the oil extraction. The seed kernel of sorghum is comprised of 30-50% oil [14]. The fatty acid compositions of sorghum oil consist of palmitic acid, stearic acid, oleic acid, linoleic acid, and linolenic acid [14], while the composition of the oil is similar to other oils, which are edible and non-edible oil purpose. Thus it is good choice as the starting oil for the production of alternative biodiesel fuel.

Most research works seek to study the factor affecting biodiesel production by transesterification of edible and non-edible oil using homogeneous catalyst [15-17]. However, use of homogeneous catalyst in biodiesel production process has problem of soap formation and difficulty in separation [18-21]. In this work, transesterification was carried out using ZnO as heterogeneous basic catalyst. The effects of reaction parameters, such as molar ratio of methanol to oil, reaction time, amount of catalyst, and reaction temperature, were optimized for the production of biodiesel.

2. Experimental

2.1 Preparation of catalyst

The transesterification of sorghum oil was carried out by using Zinc oxide as a catalyst. 10 ml of ethanol was measured and poured into a measuring flask after which 0.3644g of zinc oxide pellet was carefully added to the measuring flask. A cork was replaced tightly. The measuring flask was swirled round thoroughly for about five minutes repeatedly about six times for complete dissolution of zinc oxide pellet in ethanol to produce zinc ethoxide.

2.2 Transesterification procedures

Transesterification reactions were carried out in 250 ml three neck round bottom flask, equipped with reflux condenser. The round bottom flask was placed in water bath and magnetic stirrer with hot plate. 100 ml of sorghum oil was measured out preheated to selected temperature in round bottom flask. The prepared catalyst zinc ethoxide was the gradually added to the preheated oil feedstock. The measurement of time was stared at this point. Heating and stirring were continued at atmospheric pressure.

After the reaction, the reaction mixture was allowed to settle overnight in the separating funnel where it was separated into two layers. The upper layer consisted of ethyl ester (biodiesel), residual ethanol and catalyst, and impurities, whereas the lower layer contained a mixture of glycerol, excess of ethanol, catalyst and impurities.

The glycerol layer was drawn off and the ethyl ester layer was then washed gently with hot distilled water at 60°C until washing water pH value that was similar to that of distilled water. The wet biodiesel was then dried at 70°C under reduce pressure by rotary evaporator. Finally, the ethyl ester content in the biodiesel product was determined. The procedure was repeated by varying parameters controlling the transesterification reaction. In each biodiesel yield as well as glycerol was measured and recorded.

2.3 Factors that affect transesterification reaction

Additional experiments were conducted to study the effect of parameters such as catalyst concentration zinc oxide (ZnO), ethanol oil ratio and reaction temperature at constant mixing rate on transesterification reaction with time. The concentrations of catalyst used were 0.25%, 0.50%, 1.0%, and 1.50% by weight of the sorghum oil. The ethanol oil ratios used were 6:1, 12:1, 18:1 and 24:1 respectively. The temperature variation was 35°C, 55°C and 65°C. The most important variables which influence the transesterification reaction are: reaction temperature, ratio of alcohol to edible and non-edible oil, catalyst mixing intensity and purity of reactants. The yield of biodiesel is affected by molar ratio, reaction temperature, reaction time, moisture and water content, stirring, and specific gravity etc. [22]

3. Result and discussion

3.1 Effect of zinc oxide (ZnO) concentration

The main role of catalyst in reaction kinetics is to reduce the activation energy. Four different concentrations, (0.25, 0.50, 1.0 and 1.5 % w/w of oil) of zinc ethoxide were used to study the effect of catalyst on transesterification. It was observed in all experiments that the equilibrium conversions were achieved between 80-100 min. Moreover, the average sorghum oil biodiesel yield of 50.50, 87, 93.1 and 93 % were obtained for each of the experiment. This is shown in Figure 1. It is to be noted that at any given condition, changing catalyst concentration has no significant effect on the equilibrium conversion.

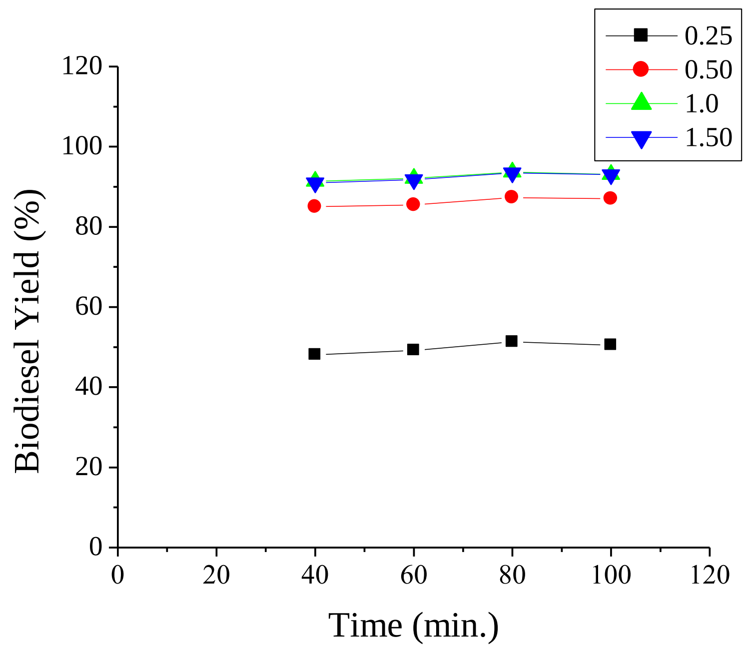

Fig.1 Effect of zinc oxide concentration on transesterification reaction

3.2 Effect of mass ratio ethanol to oil

One of the most important variables affecting the conversion of triglycerides (TG) is the molar ratio of alcohol to TGs. The stoichiometric molar ratio for transesterification is three moles of alcohol (e.g., ethanol) to one mole of TGs, to produce three moles of alkyl esters (e.g., methyl esters) and one mole of glycerol. The effect of molar ratio on transesterification reaction is associated with the type of catalyst used. It is reported in open literature, acid-catalyzed transesterification requires a molar ratio of 30:1, while alkali-catalyzed reaction requires only 6:1 molar ratio to achieve the same equilibrium conversions.

In the present study, the effects of four ratios (6:1, 12:1, 18:1 and 24:1) were investigated. Low molar ratios were considered since only alkali-catalyzed transesterification reactions with sorghum oil were carried out. Figure 2 shows the effect of ethanol - oil ratio on the transesterification reaction at different conditions. It was observed that the equilibrium conversion increased with an increase in molar ratio resulting to average sorghum oil biodiesel yield of 93.62, 93.76, 96.60 and 96.50 % respectively for each of the experiment. According to these observations, 18:1 is the optimum alcohol ratio.

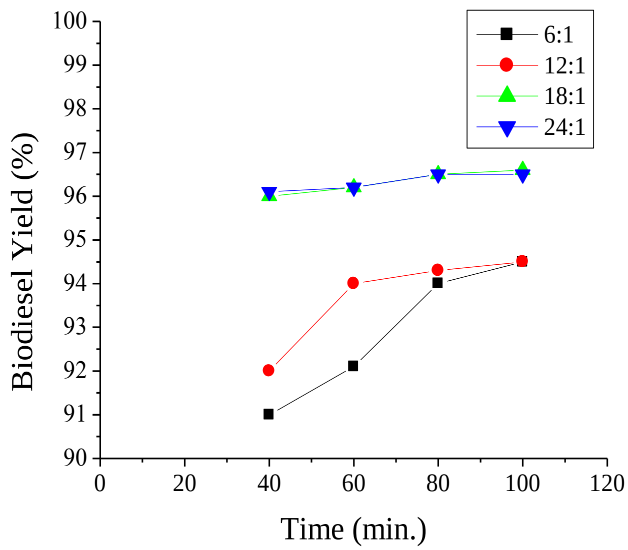

Fig. 2 Effect of ethanol-oil ratio on transesterification reaction

3.3 Effect of temperature

The effects of three temperatures (35, 55 and 65°C) on transesterification reaction have been investigated. An increase in equilibrium conversion with an increase in temperature was observed as shown in Figure 3. Due to the sampling policy, the equilibrium conversions were observed between 85-100 min in experiment two and three. The equilibrium conversions at 35, 55 and 65°C were observed to be approximately 83, 84.2 and 95.55%, respectively. Thus, it was observed that the equilibrium conversions increased substantially for every degree rise in temperature. Hence, rate of reaction is strongly dependent on temperature of reaction [23].

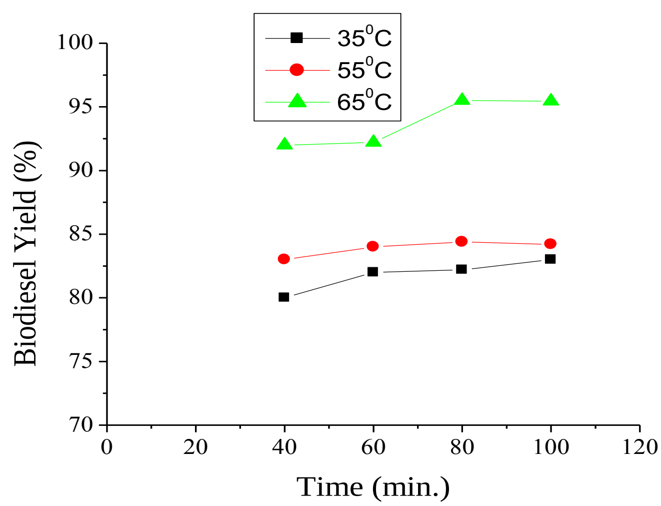

Fig. 3 Effect of temperature on transesterification

Based on this research work, the best reaction time to be used for transesterification reaction of sorghum oil to biodiesel is obtained by plotting average biodiesel yield against reaction time as shown in Figure 3. According to the plot, the best reaction time for transesterification reaction of sorghum oil to biodiesel is 100 min. It was also reported similar finding using soybeans and sunflower oil, an approximate yield of 80 % was observed after 1min with ethanol to oil ration of 6:1, 1 % zinc ethoxide catalyst at 60°C. After one hour, the conversion was almost at the same (93-98%) [23].

4. Characterization of Sorghum Ethyl ester (biodiesel)

Physical and chemical properties of sorghum biodiesel were determined by using standard method. These standard values are calculated for sorghum biodiesel and compared with ASTM D6751 (biodiesel) and ASTM D0975 (petro-diesel). Density, viscosity, specific gravity, flash point, pour point, cloud point, saponification value, iodine value and acid value are given in Table 1

Table 1 Comparison of Sorghum biodiesel with Petro-diesel and standard biodiesel

Fuel Properties	Sorghum Biodiesel	Biodiesel (ASTM D6751)	Petro-diesel (ASTM D0975
Density at 30°C(kg/m^3)	0.879	0.875-0.9	0.876
Viscosity at 40°C	3.23	1.9-6.0	1.9-4.1
Specific gravity (kg/m^3)	0.882	0.880	0.850
Flash point (°C)	160	100-170	60-80
Acid value (mg NaOH/g)	0.34	0.8	0.35
Iodine value	102	-	-
Saponification value (mg NaOH/g)	167	-	-

5. Conclusions

The effects of different reaction factors on the production of biodiesel using zinc oxide as a heterogeneous catalyst were studied. Four replicate transesterification experimental runs were carried out for each of the mixing duration 25, 50, 75, and 100 minutes under different typical transesterification reaction conditions of 100 ml sorghum oil, temperature (37°C, 57°C, and 67°C), ZnO concentration (0.25%, 0.5%, 1.0 % and 1.5%) (wt% sorghum oil), ethanol to oil ratio (6:1, 8:1, 12:1 and 24:1) at a constant mixing rate. The optimum conditions were found to be 1% ZnO, 18:1 ethanol to oil ratio, 67°C temperatures. From this study the highest conversion is 96%

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