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Full Length Research Paper

Biodiesel production from Jatropha caucus oil in a batch reactor using zinc oxide as catalyst

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This paper presents the effect of different factors that affect the conversion of Jatropha caucus (JCO) 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, and 100 min under different typical transesterification reaction conditions of 9.115 g JCO, temperature (37, 57, and 67°C), ZnO concentration (0.25, 0.5, 1.0 and 1.5%) (wt% JCO), methanol 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 methanol to oil ratio, 67°C temperature and highest yield of biodiesel obtained was 98%.

Key words: Yield, transesterification, Jatropha oil, zinc oxide.

INTRODUCTION

Majority of the world energy needs are supplied through petrochemical sources, coal, and natural gases, with the exception of hydroelectricity and nuclear energy. Of all these sources that are finite, the current usage rates will be consumed shortly. Non-renewable energy sources such as petroleum are related to several drawbacks including; increase green house emission, high cost of processing the crude petrol and energy demand during the process, non-renewable etc. This has provided incentives to seek for alternative sources for petroleum-based fuels.

Alamu et al. (2007) has reported that Nigeria currently imports about 80% of its petroleum requirements and has been hit hard by rapidly increasing cost and uncertainty. Unfortunately, in Niger Delta region, the centre of oil extraction of the country, severe environmental impacts have been ignored in the country's haste to develop the oil industry. This has generated militancy from the local people (Ijaw) making successful oil prospecting a nearly impossible task for the multinational companies in Nigeria. As a result the cost of extracting the reserve will go on increasing in Nigeria. Thus, there is an urgent need to find alternative renewable forms of energy before mineral oil supplies run dry. Hence, in the medium (2008 to 2015) and long term (2016 to 2025), Nigeria envisions an energy transition from crude oil to renewable energy (ECN, 2005). An alternative fuel must be technically feasible, economically competitive, environmentally acceptable and readily available. One possible alternative to fossil fuel is the use of oils of plant origin like vegetable oils and tree borne oil seeds. The alternative diesel fuel can be termed as biodiesel. The fuel is biodegradable, non-toxic and has low emission profiles as compared to petroleum-based diesel. Usage of biodiesel will allow balance to be sought between agriculture, economic development and the environment (Meyer et al., 2004).

Various edible and non edible vegetable oils, like rice bran oil, coconut oil, Jatropha caucus oil, castor oil, cottonseed oil, mahua, karanja which are either surplus and are non-edible type, can be used for the preparation of biodiesel (Malhotra and Das, 1999; Shah et al., 2004; Freedman et al., 1986). *Jatropha caucus* oil is considered in this research work due to its generous advantages.

Chemically the oils/fats consist of triglyceride molecules of three long chain fatty acids that are ester bounded to a single glycerol molecule. These fatty acids differ by

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length of carbon chains, the number, orientation and position of the double bounds in these chains. Thus, the biodiesel refers to as lower alkyl esters of long chain fatty acids, which are synthesized either by transesterification with lower alcohols or by esterification of fatty acid (Meyer et al., 2004). Most research works seek to study the factors affecting biodiesel production by transesterification of *Jatropha caucus* oil using homogenous catalysts (Chhetri et al., 2009; 2007; 2005). However, use of homogeneous catalyst in biodiesel production process has problems of soap formation and difficulty in separations (Abdullah et al., 2007; Alcantara et al., 2000; Ma and Hanna, 1999; Ma et al., 1998). Hence, this paper is aimed to study the factor that affect biodiesel production using heterogenous catalyst which may result in no soap formation and will make easy separations, catalyst and methanol as an alcohol.

MATERIALS AND METHODS

Equipment

The reactions were carried out in a 250 ml three-necked flat bottom flask with a reflux condenser (to reduce the loss of methanol by evaporation), thermometer and a stopper to add the catalyst solution. The reaction mixture was heated and stirred by a hot plate with a magnetic stirrer (Gupta and Sastry, 2006).

Procedure

The transesterification reaction of Jatropha oil was carried out by using zinc oxide as a catalyst. 2.0 g (2.5 ml) of methanol was measured and poured into a test tube after which 0.09114 g of ZnO pellet was carefully added to the test tube. A cork was replaced tightly. The test tube was swirled round thoroughly for about two minutes repeatedly about six times for complete dissolution of ZnO pellet in the methanol. 9.115 g (10 ml) of JCO was measured out, pre-heated to 65°C in a three-necked flat bottom flask with reflux condenser using a water bath and thermometer to observe the temperature. The pre-heated JCO is poured in a 250 ml beaker placed on a magnetic stirrer. The prepared zinc methoxide from the test tube was carefully poured into the JCO. Then the beaker was secured tightly using a stopper and the magnetic stirrer switched on and moderate agitation in the beaker was maintained for 25 min. The mixture was poured from the beaker into a second test tube for settling and the top secured using cork. The reaction mixture was allowed to stand overnight while phase separation occurred by gravity settling into golden/pale liquid biodiesel on the top with the light brown glycerol at the bottom of the test tube. The JCO biodiesel was carefully decanted into a plastic test tube (pierced at the bottom) leaving the glycerol at the based. The biodiesel was washed with water as detailed in Alamu (2007).The procedure was repeated by varying parameters controlling the transesterification reaction. In each case biodiesel yield as well as glycerol yield was measured and recorded.

Factors that affect transesterification reaction

Additional experiment were conducted to study the effect of parameters such as catalyst concentration (ZnO), Methanol-oil ratio and reaction temperature at constant mixing rate on transesterification reaction with time. The concentration of catalyst used were 0.25, 0.50, 1.0, and 1.5% by weight of the JCO. The methanol-oil ratios used were 6:1, 12:1, 18:1 and 24:1, respectively. The temperature variation was 35, 55 and 65°C. ASTM standard fuel tests were subsequently carried out on the JCO biodiesel and low sulphur diesel fuel (No. 2 diesel) purchased at a fuel station in Maiduguri, Nigeria. Specific gravity and viscosity measurements were made using the thermal-Hydrometer apparatus and viscometer (Canon-Fenke calibrated, 15cSt max. range), following ASTM Standards D 1298 and D 445, respectively. The biodiesel was analyzed for cloud point and pour point using Baskeyl Sate point cloud and pour point apparatus following ASTM standard D 25100-8 and D 97, respectively (ASTM, 1995).

RESULTS AND DISCUSSION

Transesterification reactions were carried out with Jatropha oil with different reaction conditions, shown in Figures 1, 2, and 3. The effect of the different process variables; catalyst concentration, alcohol to oil ratio, temperature of the reaction and reaction time were analyzed experimentally.

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 sodium hydroxide were used to study the effect of catalyst on transesterification. It was observed in all experiments that the equilibrium conversions were achieved between 80 to 100 min. Moreover, the average JCO biodiesel yield of 51.93, 87.22, 93.89 and 93.89% 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.

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 (for example, methanol) to one mole of TGs, to produce three moles of alkyl esters (for example, 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 Jatropha oil were carried out. Figure 2 shows the effect of alcohol- 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 JCO biodiesel yield of 93.14, 93.46, 96.46 and 96.46%, respectively for each of the experiment. This is in

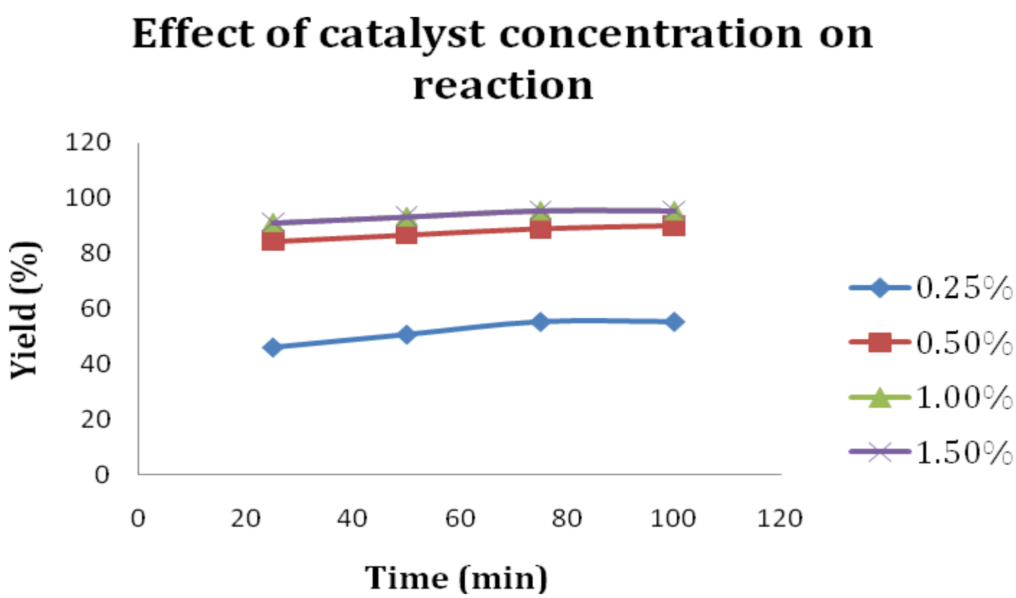

Figure 1. Effect of zinc oxide (ZnO) concentration on transesterification reaction.

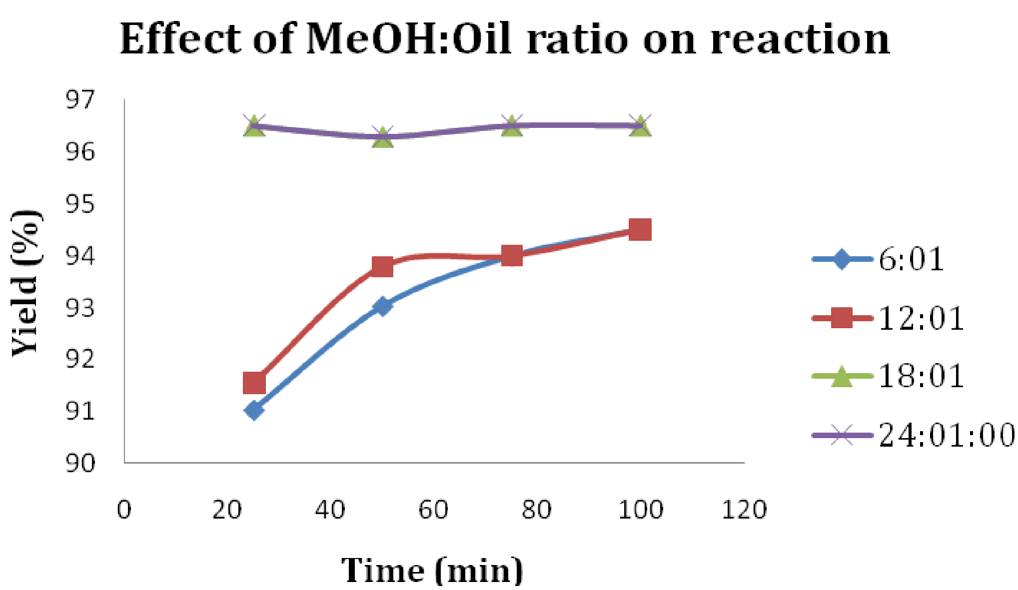

Figure 2. Effect of methanol-oil ratio on transesterification reaction.

agreement with theory (Le Chateliers principle). According to these observations, 18:1 is the optimum alcohol ratio.

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 to 100 min in experiment two and three. The equilibrium conversions at 35, 55 and 65°C were observed to be approximately 81.75, 83.85 and 93.75%, 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.

Based on this research work, the best reaction time to be used for transesterification reaction of JCO to biodiesel is obtained by plotting average biodiesel yield

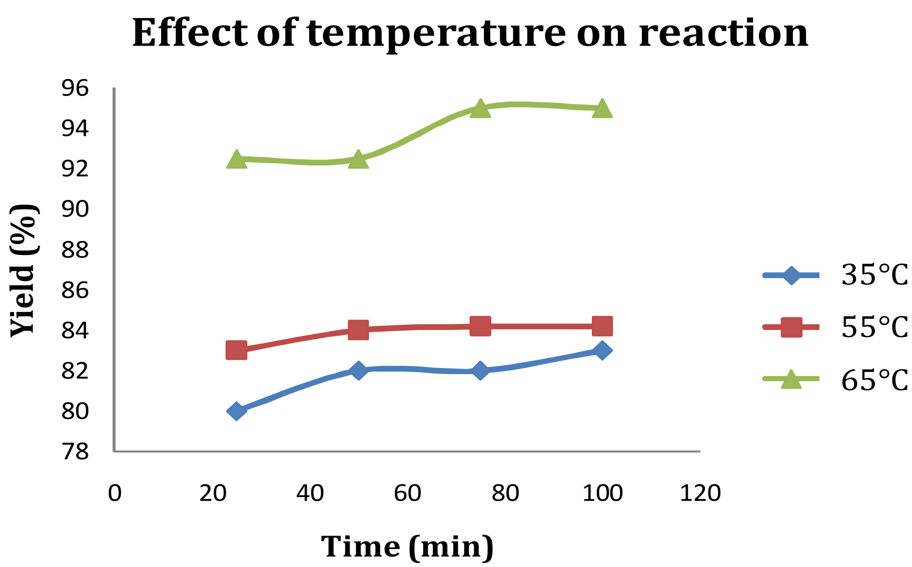

Figure 3. Effect of temperature on transesterification reaction.

against reaction time as shown in Figure 3. According to the plot, the best reaction time for transesterification reaction of JCO to biodiesel is 100 min. Dorado et al. (2002) also reported similar finding using soybeans and sunflower oil, an approximate yield of 80% was observed after 1 min with methanol to oil ration of 6:1, 1% zinc methoxide catalyst at 60°C. After one hour, the conversion was almost the same (93 to 98%).

Conclusions

The effects of different reaction factors on the production of biodiesel using zinc oxide as a hetereogeneous catalyst were studied. Four replicate transesterification experimental runs were carried out for each of the mixing duration 25, 50, 75, and 100 min under different typical transesterification reaction conditions of 9.115 g JCO, temperature (37, 57, and 67°C), ZnO concentration (0.25, 0.5, 1.0 and 1.5%) (wt% JCO), methanol 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 methanol to oil ratio, 67°C temperature. From this study the highest conversion is 98%.

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