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RESEARCH ARTICLE

Optimization of Biodiesel Production from Waste Cooking Oil by Alkaline Catalysts

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Abstract

Biodiesel is a renewable and clean energy which can be used exclusively or in mixtures with petroleum-derived fuels. In this study, biodiesel was produced from waste cooking oil using two catalysts including KOH and NaOH. For this purpose, the effects of several parameters such as temperature, methanol to oil ratio, reaction time and amount of catalyst on biodiesel yield were investigated. The optimal conditions of temperature, methanol to oil ratio, reaction time and amount of catalyst in biodiesel production were obtained 60 °C, 1:6, 90 minutes and 1 wt. %, respectively. The efficiencies of biodiesel production by KOH and NaOH in optimal conditions were obtained 94 and 85%, respectively. Thus, KOH shows better performance as the catalyst to the biodiesel production. Additionally, the characteristics of biodiesel fuels have been characterized by employing standard experiments.

Keywords: Biodiesel; Waste Cooking Oil; Alkaline Catalyst; Optimization

Introduction

In recent years the increase in world population, expanding industry and technology is reducing fossil fuel resources. Recently, research has been done to develop the exploration of renewable energy resources. One of these sources is biodiesel. Biodiesel is comprised of esters of short-chain alcohols made from renewable biological sources such as vegetable oil and animal fats and can be used as an alternative diesel fuel [1-3]. Biodiesel can be produced from the used cooking oil including triglycerides. Vegetable oils have become more attractive recently because of their environmental benefits and the fact that it is made from renewable resources [4]. Biodiesel is simple to use, biodegradable, non-toxic, and more importantly free of sulfur and aromatics [5-6]. Feedstocks for producing biodiesel include soybean oil Moringa oil, sunflower oil, rapeseed oil, palm oil, jatropha oil, camelina oil, neem oil, Karanja oil, sesame oil, chicken fat, and goat fat [7-20]. Biodiesel consists of alkyl monoester derived from renewable raw materials such as oils mentioned above. It is usually produced by trans-esterification reaction carried out between the triglyceride oil and an alcohol. Alcohols such as methanol, ethanol, or butanol can be used in the transesterification [21-22]. Biodiesel production is influenced by parameters such as temperature, methanol to oil ratio, type of catalyst and etc. [23-25].

Nowadays, most biodiesel is produced using homogenous base catalysts, such as sodium hydroxide (NaOH) or potassium hydroxide (KOH). The reasons for using these catalysts are as follows: the ability to catalyze reactions at the low reaction temperature and atmospheric pressure, and the achievement of high conversion in a minimum time [26]. Today, other catalysts such as Wo3 supported on $AlPo_4$ [nano- $CaO/CuFe_2O_4$ nano-CaO and mixed Oxides TiO_2-MgO are used for the production of biodiesel [18,19,27,28].

The objective of this study was to elucidate the biodiesel production from waste cooking oil using sodium and potassium hydroxide as catalyst. To do this, the effects of some parameters including temperature, time of trans-esterification, methanol to oil ratio, catalyst concentration, and type of catalyst were investigated and optimum values were obtained.

Materials and Methods

Materials

Waste cooking oil was collected from the local restaurants of Dashtestan and Boushehr cities. To remove food particles from the waste oil, it was filtered by vacuum pump using Whatman filter paper number 41. After separating food particles, oil was stored in plastic bottles at room temperature. Methanol (purity > 0.99) was purchased from Mojallali Company (Iran) and potassium hydroxide (KOH), sodium hydroxide (NaOH) and sodium sulfate (Na_2So_4) were purchased from Merck Company (Germany).

Biodiesel Production

To prepare the biodiesel, 240 gr (0.27 moll) of waste cooking oil was poured into the flask and placed on a heater to achieve the desired temperature. 52 g (1.62 mol) of methanol and 1 wt % (2.4 g) of catalyst (NaOH and KOH) were then added to the oil. The mixture was mixed for 10-15 min and the methoxide solution was obtained [20].

The produced methoxide was added to the waste oil at the desired time and temperature (60 °C for 60 min) and was placed on the heater. It was then mixed with a magnetic stirrer with a stirrer speed of 600 rpm to do transesterification reaction. After the time required for the transesterification reaction, the collected solution was poured into a separator funnel and cooled to the desired temperature for 24 hours. Finally, the solution in the funnel was divided into two phases: upper phase containing the product (biodiesel) and the bottom phase containing glycerol and excess catalyst (Figure 1 and 2). The following equation was used to calculate the biodiesel yield.

$$Biodiesel\ yeild\ (\%) = \frac{Weight\ of\ biodiesel}{Weight\ of\ oil} \times 100 \tag{1}$$

Figure 1: Biodiesel produced by potassium hydroxide catalyst

Figure 2: Biodiesel produced by sodium hydroxide catalyst

Obtaining Optimal Conditions

The waste cooking oil and methoxide were mixed with different ratios (1:2, 1:3… 1:8) at 60 °C for 60 min to determine the optimum ratio of oil to methanol. The effect of different concentrations of catalyst (0, 1, 1.5 and 2 wt. %) on the biodiesel production was also evaluated and the optimum value of the catalyst concentration was obtained. Additionally, the effects of reaction time (10-90 min) and temperature (10-80 °C) at the optimum values of oil to methanol ratio and catalyst concentration were determined.

Washing and Purification of Biodiesel

To remove the catalyst, the product (biodiesel) was washed several times with hot distilled water. To absorb the water of biodiesel, 13 grams of sodium sulfate was then added to that. Additionally, to evaporate any remaining water, the product was heated by rotary evaporator at 70 °C for 30 min. Finally, the obtained biodiesel was stored in a plastic bottle and analyzed (Figure 3) [29].

Figure 3: BBiodiesel produced from potassium hydroxide (right) and sodium hydroxide (left)

Biodiesel Analysis

To determine the characterization of biodiesel, different analyses were carried out according to the ASTM and EN. The analysis was done to measure viscosity at 40 °C according to ASTM D445 and the flash point, the distillation temperature, color, the number of cetane according to ASTM D93, ASTM D1160, ASTM D1500, ASTM D613, respectively.

Results and Discussion

The effect of catalyst concentration and oil to methanol ratio

In this study, different concentrations of catalysts (KOH and NaOH) including 0, 0.5, 1, 1.5 and 2 wt. % on the biodiesel production were investigated. Effect of catalysts concentration is displayed in Figure 4. Also, the optimum conditions are reported in Table 1. When the reaction was carried out without the use of catalysts, the amount of biodiesel production was very low that could be omitted. The activation temperature was 60 °C for both catalysts. As shown in Figure 4, the biodiesel production was increased with increasing catalyst concentrations of 1 wt. %. However, when the catalyst concentration was increased from 1 to 2 wt %, the amount of biodiesel production decreased.

Optimum value	Parameter
1:06	Ratio of oil to methanol
1%	Catalyst amount for both(%w/w)
60	Temperature (°C)
90	Time (min)
94	Efficiency KOH (%)
85	Efficiency NaOH (%)

Table 1: POptimal conditions for biodiesel production

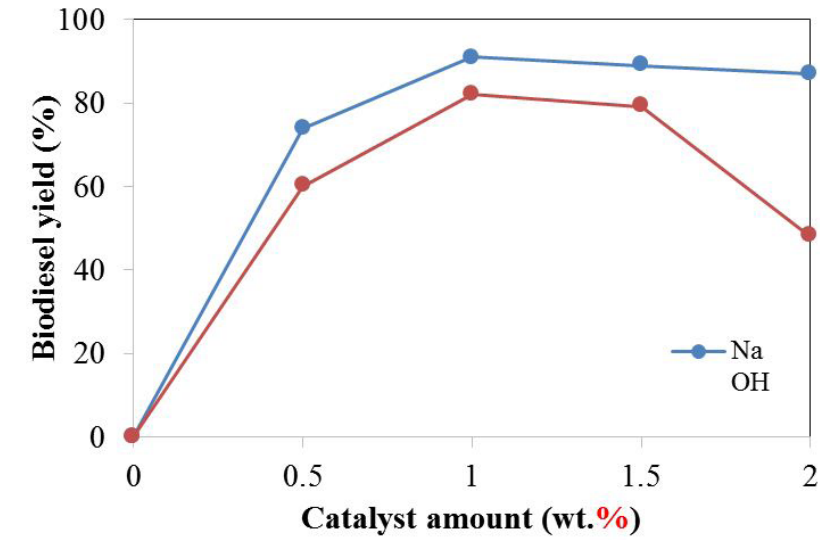

Figure 4: The Effect of Ratio of Oil to Methanol on Efficiency

The ratio of oil to methanol (1:2, 1:3 and ... 1:8) was then investigated in biodiesel production and is showed in Figure 5. At the beginning of the reaction, by increasing the ratio of waste cooking oil to methanol, the biodiesel yield was increased. But in the ratio of 1:7, the amount of the biodiesel was decreased and continued to the ratio of 1:8. These results have also been obtained in the study of Suzana Yusup *et al.* [27]. The results also showed that the best ratio of oil to methanol was 1:6 to produce the biodiesel.

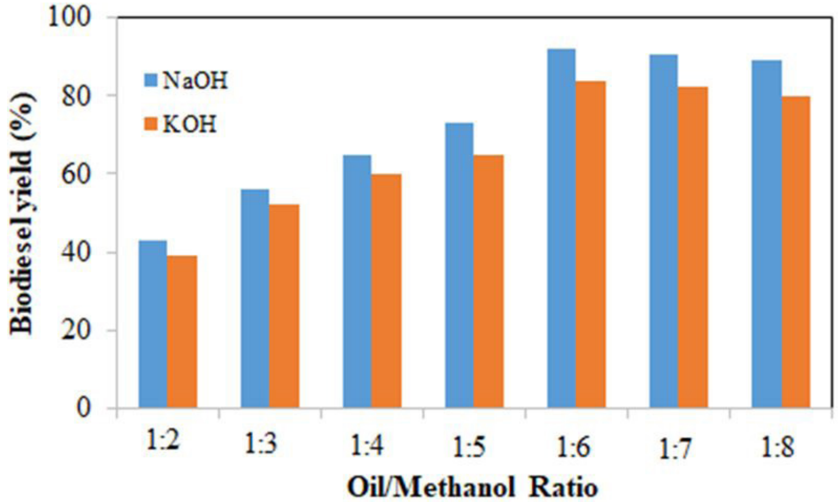

Figure 5: Effect of catalyst amount on the biodiesel yield

Effect of Time and Temperature

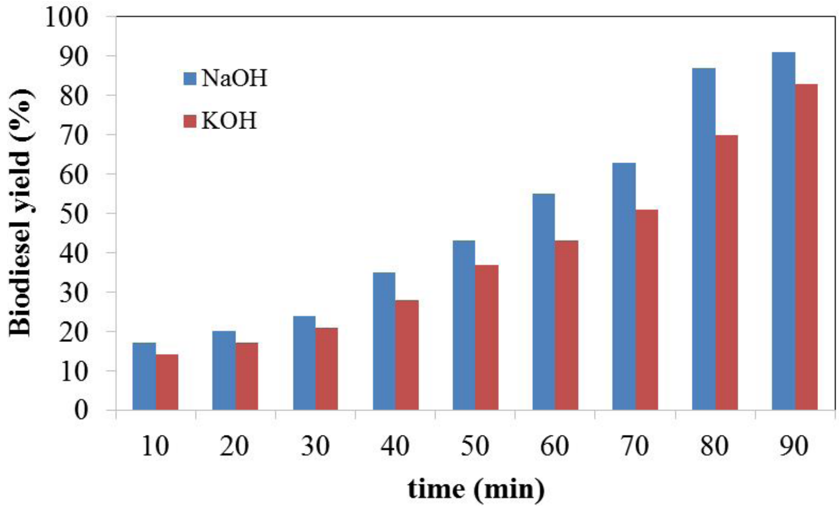

Figure 6: Effect of time on the biodiesel yield

Other important parameters on the biodiesel production (FAME) are time and temperature. To study the effect of time, the effect of several reaction time including 10, 20, 30, ... , 90 min were investigated. The results are shown in Figure 6. This process was performed in the oil to methanol ratio, temperature and catalyst concentration of 1:6, 60 °C and 1 wt. %, respectively.

At the beginning of the reaction, The catalyst is not fully activated and is activated over time which the biodiesel production has increased. Results related to the both catalysts are shown in Figure 6. The results also cleared the maximum biodiesel production was obtained at 90 min.

As mentioned above, in addition to the effective and important parameters such as time, amount of catalyst and ratio of oil to methanol on the biodiesel production, the temperature can be also considered. For this purpose, the effect of some temperatures including 40, 50, 60, 70 and 80 °C was studied. At the beginning of the process, the production efficiency increased with increasing temperature, but after temperatures of 60 °C, the efficiency decreased. These results could be explained as follows: At the beginning of the process as the temperature starts rising, the productivity increases due to the activation of the catalyst and acceleration of the reaction. But when the reaction temperature reaches to 70 °C or more, methanol is evaporated, which reduces the amount of methanol for its reaction to oil and catalyst. Thus, the efficiency is reduced. Despite the installation of the condenser to prevent loss of methanol from the reaction flask, it takes time to return methanol to reaction flask in order to participate in the reaction. Thus, the time delay reduced the efficiency. The results of temperature effects are shown in Figure 8.

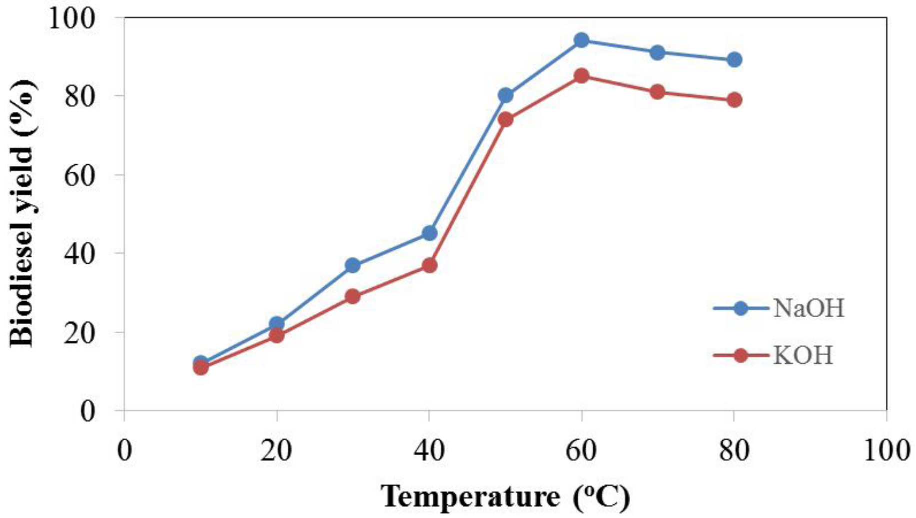

Figure 7: Effect of temperature on the biodiesel yield

Theoretical Observations

Figure 8: Glycerol produced by 2 wt % of sodium hydroxide catalyst

After the transesterification process and formation of two-phase product in the separator funnel, glycerol and biodiesel (FAME) were placed at the bottom and top of the funnel. It can be concluded that glycerol is heavier than the produced biodiesel (Figures 1 and 2). The produced glycerol by KOH was a viscous liquid, while the glycerol produced by NaOH was a solid as gel. These different forms have been observed in all experiments. The reason for this is unknown and hasn't been reported in any of the previous investigations. But one possible reason could be that sodium hydroxide is more reactive than potassium hydroxide. Results are clear in Figures 9 and 10.

Figure 9: Glycerol produced by 2 wt % of potassium hydroxide catalyst

Analysis of Biodiesel Produced by Catalyst KOH And NaOH

After reviewing the important factors affecting and determining the optimal conditions, biodiesel was produced and sampled. The analysis was performed according to ASTM and EN standards. The results showed in Tables 2 and 3.

Properties	Unit	Value	ASTM	EN
Density	Kg/m^3	877	--------	860-900
Flash point	°C	164	130 (min)	120 (min)
color	--------	1.5	3 (max)	--------
Cetane number	--------	53	47 (min)	51 (min)
Distillation temperature	°C	316	360 (max)	--------
Kinematic viscosity	mm^2/sec	4.3	1.9-6	3.5-5

Table 2: Characteristics of biodiesel produced by potassium hydroxide catalyst

Properties	Unit	Value	ASTM	EN
Density	Kg/m^3	878	--------	860-900
Flash point	°C	196	130(min)	120(min)
color	--------	1.5	3(max)	--------
Cetane number	--------	55	47(min)	51(min)
Distillation temperature	°C	320	360(max)	--------
Kinematic viscosity	mm^2/sec	4.6	1.9-6	3.5-5

Table 3: Characteristics of biodiesel produced by Sodium hydroxide catalyst

Conclusion

In this research, biodiesel was produced from waste cooking oil by KOH and NaOH as two efficient catalysts. The effects of some parameters including reaction time, catalyst concentration, temperature and oil to methanol ratio were studied and the optimum conditions were obtained. The results showed that the optimal values for oil to methanol ratio, catalyst concentration, Temperature and reaction time were obtained 1:6, 1 wt. %, 60 °C, and 90 min, respectively. The efficiency of produced biodiesel by KOH and NaOH in optimal conditions were 94 and 85% and analyzed according to ASTM and EN standards. It was concluded that the produced biodiesel can be burned as fuel to replace petroleum-derived fuels or it can be mixed with petroleum-derived fuels as new fuel.

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