Optimization of Biodiesel Production from Used Vegetable Oil based on its Kinematic Viscosity

Ritica Ramakrishnan[1], Tushar Jash[2*]
[1]*School Energy Studies, Jadavpur University, Kolkata-700032, India*
[2]*School Energy Studies, Jadavpur University, Kolkata-700032, India*

Abstract

Used vegetable oil is an excellent feedstock for biodiesel production. The process parameters of the production procedure affect the properties of the biofuel. Factors like reaction temperature, reaction time, molar ratio of alcohol to oil, catalyst concentration and stirring rate affect transesterification of used vegetable oil. Biodiesel has been produced from used vegetable oil collected from a shop that sells savoury snacks in Kolkata. A maximum yield of biodiesel of 94% has been achieved by transesterification reaction with methanol in presence of potassium hydroxide as catalyst. The kinematic viscosity of biodiesel was measured and based on the results the process parameters have been optimized. Important properties of biodiesel produced from used vegetable oil were also measured.

1. Introduction

Biodiesel is an environment-friendly liquid fuel. It is biodegradable, emits less emission during combustion in IC engines and has almost the same properties as petroleum diesel. Used vegetable oil is considered waste, as it cannot be reused as a cooking medium. Thus, this oil can be used for biodiesel production instead of throwing it away. Many methods have been adopted for the production of biodiesel from used vegetable oil. Those include transesterification with base catalyst, transesterification with acid catalyst, enzymatic conversion and non-catalytic transesterification using methanol [1]. Transesterification with base catalysts is the most preferred method and has been used for a long time. The process has higher catalytic efficiency, lower cost and lower reaction temperature and pressure [2]. Many researchers have used potassium hydroxide as the base catalyst and have found successful results [3]. Shimada et al. have stated in their study that potassium hydroxide was considered the best catalyst for transesterification using waste vegetable oil [4]. Tomasevic and Siler-Morinkovic have reported producing biodiesel from waste sunflower oil by varying molar ratios of methanol to oil (4.5:1, 6:1, and 9:1) base catalysts potassium hydroxide and sodium hydroxide [5]. Refaat et al. investigated biodiesel production from waste cooking oil at different molar ratios of methanol to oil (3:1, 6:1, and 9:1), KOH and NaOH as catalyst with different concentrations (0.5% and 1% w/w) and reaction temperatures (25°C and 65°C) [6]. Used vegetable oil requires pre-processing before the transesterification reaction. In many studies, they have used steam injection [7], column chromatography [8], film vacuum evaporation [9], and vacuum filtration. On a daily basis the shop vendor cleans out his fryer and throws away 1 kg to 2 kg used vegetable oil mixed with carbon and fried pieces of batter. This mixture is processed before the transesterification reaction. From 1 kg of this oily mixture 800 ml of used vegetable oil is obtained after removal of all impurities.

In this study used vegetable oil, collected from a shop that sells nimki (fried flour batter/savoury snacks) in Kolkata, was used for biodiesel production. Potassium hydroxide was used as base catalyst. Kinematic viscosity of a fuel affects the atomization of the fuel in an IC engine. Lesser the value of kinematic viscosity, better the atomization of fuel. This facilitates efficient burning of the fuel inside the IC engine. The objective of this paper was to optimize the process parameters like reaction temperature, molar ratio of alcohol to oil, catalyst concentration and reaction time of the production procedure of biodiesel with respect to the kinematic viscosity of the produced biodiesel.

2. Materials and methods

2.1 Materials used

Used vegetable oil collected from a shop that sells nimki (fried snacks made of refined flour) was used as feedstock. Methanol of 99% purity was used from Merck Ltd. Potassium hydroxide of 84% purity was used from Merck Ltd.

2.2 Experimental method for production of biodiesel

Used vegetable oil was first passed through a funnel with cotton waste placed in its mouth. To remove the finer carbon particles this oil was then filtered by vacuum filtration. This experimental setup consisted of a sintered glass filter (grade G4) fitted in a Buchner conical flask. The vacuum was created by a vacuum pump attached to the Buchner flask. A calculated amount of methanol and potassium hydroxide were stirred till the catalyst completely dissolved. Then 100g used vegetable oil was added to the mixture and stirred under reflux for a stipulated amount of time at stirring rate of 1000 rpm. The apparatus used for the transesterification reaction was a 500ml conical flask fitted with a reflux condenser on a magnetic stirrer. The reaction was carried out at different temperatures ranged from 40°C to 60°C. The catalyst concentration was varied from 0.5% to 1.5% ((weight of catalyst/ weight of oil)%). The molar ratio of alcohol to oil was varied from 3:1 to 12:1. The reaction time was also varied from 1 hour to 3 hours. The reaction mixture was allowed to stand overnight after the stipulated reaction time. The mixture separated into two phases, lower phase being glycerol and upper phase being methyl ester or biodiesel. The biodiesel was repeatedly washed with warm water to remove excess potassium hydroxide. After washing, the biodiesel was heated in an air oven at 80°C for 20 minutes. The yield of biodiesel was measured finally. Tables 1 to 4 show the change in the yield of biodiesel as the process parameters were changed.

Table 1. Experimental data when reaction temperature was varied

Constant reaction parameters: Reaction time=2 hours, Stirring rate=1000rpm, Catalyst concentration=1%, Molar ratio of alcohol to oil=8:1			
Reaction temperature (°C)	Mass of used vegetable oil (g)	Mass of biodiesel produced (g)	Yield (%)
40	100	94	94
45	100	90	90
50	100	92	92
55	100	90	90
60	100	86	86

Table 2. Experimental data when catalyst concentration is varied

Constant reaction parameters: Reaction time=2 hours, Stirring rate=1000rpm, Reaction temperature=40°C, Molar ratio of alcohol to oil=8:1			
KOH concentration (w/w%)	Mass of used vegetable oil (g)	Mass of biodiesel produced (g)	Yield (%)
0.5	100	92	92
1.0	100	94	94
1.5	100	90	90

Table 3. Experimental data when reaction time was varied

Constant reaction parameters: Reaction temperature=40°C, Stirring rate=1000rpm, Catalyst concentration=1%, Molar ratio of alcohol to oil=8:1			
Reaction time (hour)	Mass of used vegetable oil (g)	Mass of biodiesel produced (g)	Yield (%)
1	100	88	88
1.5	100	90	90
2	100	94	94
3	100	94.5	94.5

Table 4. Experimental data when molar ratio of alcohol to oil was varied

Constant reaction parameters: Reaction temperature=40°C, Stirring rate=1000rpm, Catalyst concentration=1%, Reaction time=2 hours			
Molar ratio of alcohol to oil	Mass of used vegetable oil (g)	Mass of biodiesel produced (g)	Yield (%)
3:1	100	82	82
4.5:1	100	88	88
6:1	100	90	90
8:1	100	94	94
9:1	100	92	92
12:1	100	92	92

2.3 Testing of biodiesel

To determine the optimum parameters for production procedure the kinematic viscosity of all the biodiesel samples were measured at 30°C by Ostwald's viscometer, using water as the reference liquid. There were totally 16 biodiesel samples made from used vegetable oil. The density was measured with help of a specific gravity bottle. The biodiesel samples were stored in glass bottles for months to check for its longevity. The flash point of biodiesel was measured using Pensky Martens Closed Tester. The calorific value of biodiesel was estimated using Bomb Calorimeter.

3. Results and Discussion

The procedure for biodiesel production depends on the reaction temperature, reaction time, molar ratio of alcohol to oil, catalyst concentration and the stirring rate. These parameters determine the quality of biodiesel produced. The reaction parameters were optimized with respect to the kinematic viscosity of all the biodiesel samples. When the reaction temperature is varied from 40°C to 60°C the yield of biodiesel remains almost the same but the kinematic viscosity increases as the temperature is increased (Fig 1). This could be due to loss in methanol as its boiling point is little above 60°C. Yield does not change much even when catalyst concentration is varied from 0.5% to 1.5% (Fig 2). Catalyst concentration less than 0.5% yield of biodiesel was not significant. Catalyst concentration more than 1.5% resulted in a soapy emulsion during washing of biodiesel and made separation difficult. As the molar ratio of alcohol to oil was increased the yield of biodiesel also increased and the kinematic viscosity decreased (Fig 3). The percentage of conversion of used vegetable oil to biodiesel increased as volume of methanol was increased. Thus decreasing the kinematic viscosity. The reaction time was varied from 1 hour to 3 hours. The longer the reaction took place, the rate of conversion of used vegetable oil increased (Fig 4). The changes in kinematic viscosity of the samples of biodiesel with varying parameters are shown in Figures 1 to 4. These Figures also show the variation of yield of biodiesel corresponding to the change in the reaction parameters. The optimum parameters for biodiesel production from used vegetable oil were estimated and are given in Table 5. The density of biodiesel was measured as 0.86 g/cc. The flash point was measured as 179°C. The calorific value was measured as 32.8 MJ/kg. The properties of biodiesel showed that they were comparable to No. 2 diesel. This is illustrated in Table 6.

Table 5. Optimum parameters for production of biodiesel from used vegetable oil

Reaction temperature (°C)	Catalyst concentration (w/w%)	Reaction time (hour)	Molar ratio of alcohol to oil	Volume of methanol used (ml)	Mass of used vegetable oil used (g)	Mass of biodiesel produced (g)	Yield (%)
40	1.0	2	6:1	30	100	90	90
40	1.0	2	8:1	40	100	94	94
40	1.0	1.5	8:1	40	100	90	90

Table 6. Comparison of the properties of biodiesel from used vegetable oil and No. 2 diesel

Properties of fuel	Biodiesel from used vegetable oil	No.2 diesel[a]
Density (g/cc)	0.86	0.85
Kinematic viscosity (centistokes)	5.24 at 30°C	1.9-4.1 at 40°C
Calorific value (MJ/kg)	32.8	42.7
Flash point (°C)	179	52 (minimum)

[a]Gerpen et.al; 2004.

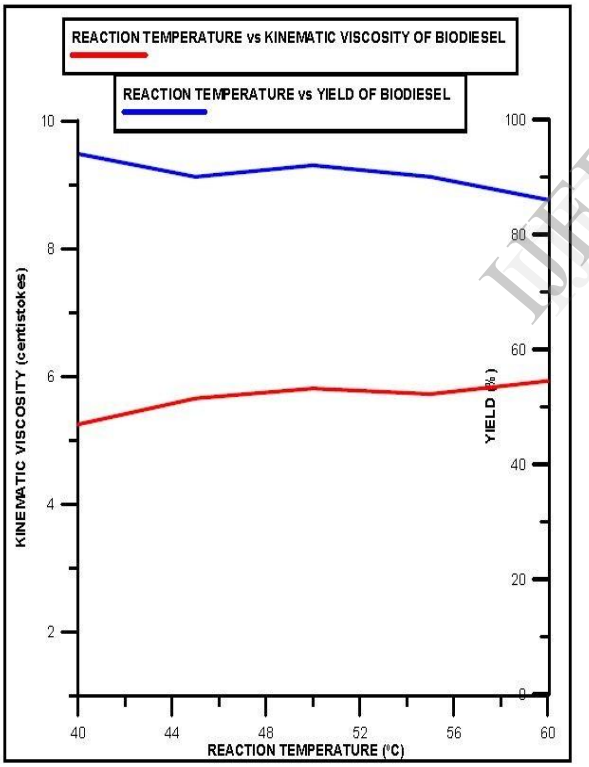

Figure 1. Reaction temperature vs kinematic viscosity and yield of biodiesel

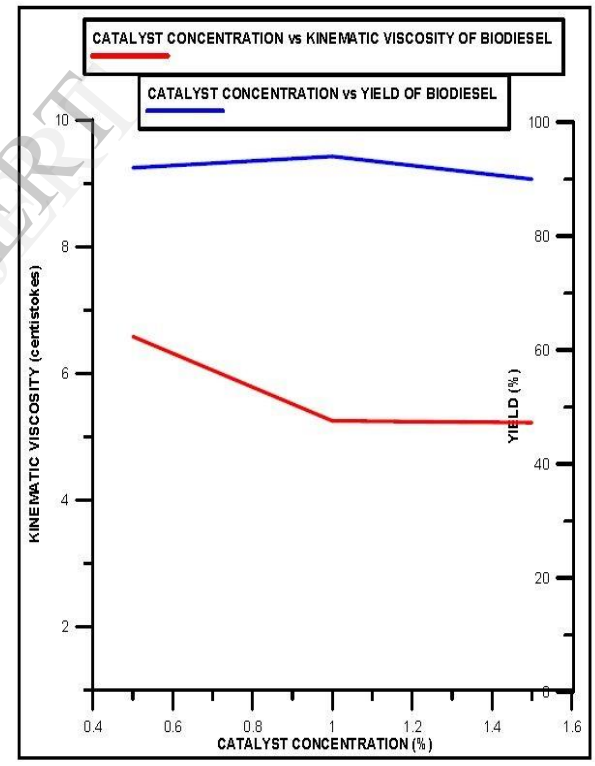

Figure 2. Catalyst concentration vs kinematic viscosity and yield of biodiesel

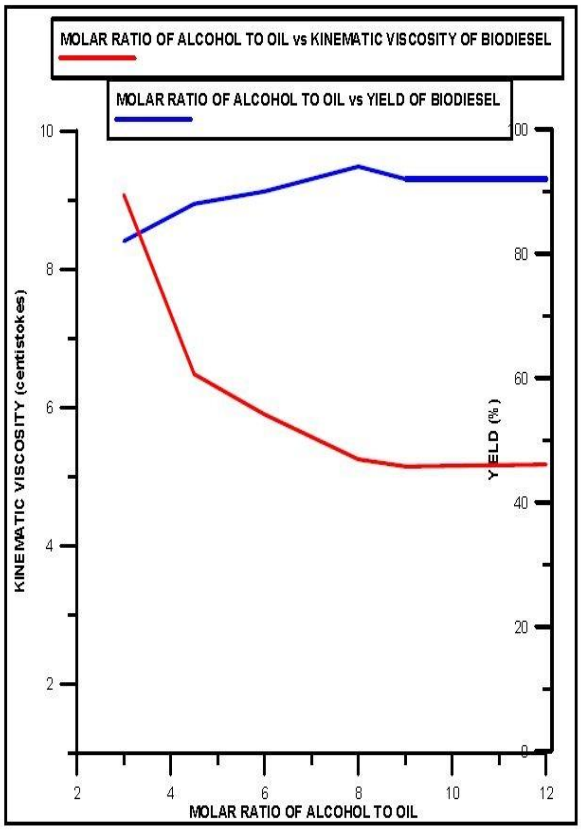

Figure 3. Molar ratio of alcohol to oil vs kinematic viscosity and yield of biodiesel

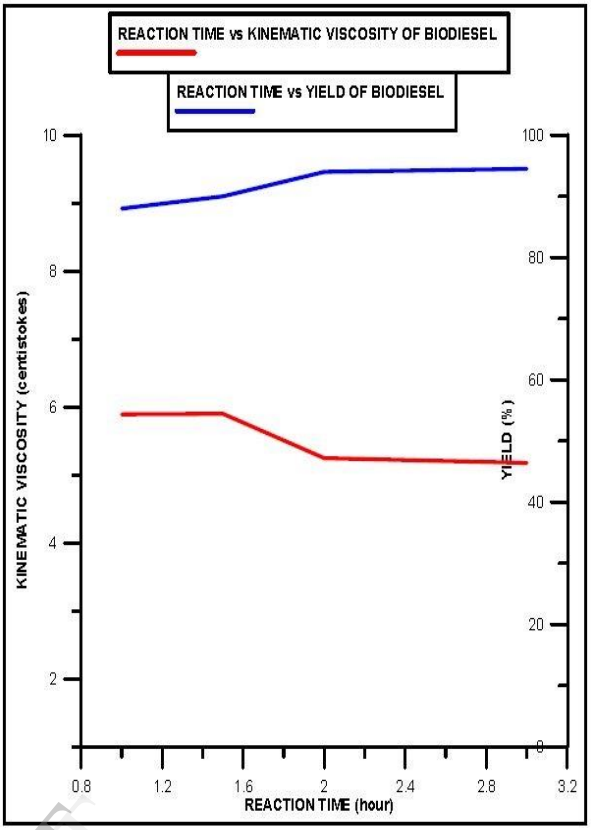

Figure 4. Reaction time vs kinematic viscosity and yield of biodiesel

4. Conclusion

- Used vegetable oil is a suitable feedstock for the production of biodiesel.
- Optimum conditions for biodiesel production were attained at 6:1 and 8:1 molar ratios of alcohol to oil at which the kinematic viscosity is minimum and the yield is quite high.
- Properties of biodiesel from used vegetable oil are comparable to fossil fuel diesel.
- Cost of production is less than that of biodiesel production from refined vegetable oil.
- The present experimental studies support the fact that methyl ester of used vegetable oil can be successfully used as an alternative for petroleum diesel.

5. References

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