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Biodiesel production from used vegetable oil collected from shops selling fritters in Kolkata

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Abstract

Used vegetable oil is an important feedstock for biodiesel production. Biodiesel has been produced from used vegetable oil collected from shops selling fritters in Kolkata. Transesterification is affected by factors like oil to alcohol ratio, concentration of catalyst used, temperature, stirring rate and reaction time. The process parameters were optimized and a maximum biodiesel yield of 94% has been achieved. Important properties of the biodiesel like density, flash point, calorific value and viscosity have also been estimated.

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Keywords: Used vegetable oil; transesterification; fritters shops; biodiesel.

1. Introduction

Energy consumption of the world is ever increasing. This has caused the fuel resources like petroleum dwindle. An alternative for petroleum is biodiesel. It has the same properties as fossil fuel diesel, is biodegradable and has lower emissions. Biodiesel is a product of a chemical reaction involving vegetable oil or animal fat, alcohol and a catalyst. The feedstock mainly used for transesterification is edible vegetable oil. But this puts a strain on developing countries using this oil for cooking purposes. The solution to this problem would be to use used vegetable oil for production of biodiesel. Used vegetable oil is a by-product from hotels, restaurants and shops selling fritters. In Kolkata, fritters are a popular snack. The shops selling these fritters run very successful businesses. These shops usually throw away the used oil as using it the next day decreases the quality of the fritters.

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By using used vegetable oil for biodiesel production handles the problem for waste management. A single shop can provide about 150 ml to 200 ml of impure used vegetable oil in a day. The city of Kolkata is divided into mainly 5 Municipal areas namely, Kolkata municipality, Dumdum municipality, North Dumdum municipality, South Dumdum municipality and Bidhannagar municipality. These municipalities collectively cover an area of 251.66 km^2. A total of 254 wards are under these municipalities [1, 2, 3, 4]. A ward has about 15 to 20 fritter shops. The used vegetable oil contains a wide variety of fatty acids in it. Used vegetable oil has more fatty acids than refined vegetable oil. Thus, the processing of the former is slightly different than the latter. Many researchers have successfully converted used vegetable oil into biodiesel [5, 6, 7, 8]. Tomasevic and Siler-Morinkovic reported the results of biodiesel production from waste sunflower oil with different molar ratios of methanol to oil [6]. Refaat et al. investigated biodiesel production from waste cooking oil with 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 and 65ºC) [7]. Allawzi and Kandah reported the transesterification of waste soybean oil with different ethanol concentration [8]. Majority of researchers have used NaOH catalyst for transesterification reaction and believed that it is the best catalyst for waste cooking oil [9]. The base catalysts are preferred over acid catalysts, owing to their capability of completion of reaction at higher speed, requirement of lower reaction temperature, and their higher conversion efficiency as compared to acid catalysts. But no work appears to have been reported on biodiesel production from used vegetable oil collected from shops selling fritters, especially in Kolkata. The present study deals with the production of biodiesel from used vegetable oil collected from fritter shops. The objective of the study was to optimize the process parameters like temperature, oil to alcohol ratio, catalyst concentration and reaction time with respect to maximum yield of biodiesel.

2. Feedstock characterisation

Feedstock used for this process was used vegetable oil. The oil was collected from a number of shops in Kolkata that sell fritters. These shops used palm oil, soybean oil, rapeseed oil and sometimes a mixture of these oils. The density of feedstock was measured in the beam balance with a specific gravity bottle. The kinematic viscosity was measured at 30ºC with the help of Ostwald viscometer with water as the reference liquid. These properties are given in Table 1. The fatty acids composition of refined vegetable oil used in the fritter shops are given in the Table 2 [10].

Table 1. Properties of used vegetable oil collected from fritter shops

Properties	Values
Density	0.91 g/cm^3
Kinematic viscosity	65.66 centistokes

Table 2. Fatty acids profile of vegetable oils

Oil	Fatty acid profile							
	Myristic (Tetradeca-noic) C14	Palmitic (Hexadeca-noic) C16	Stearic (n-Octadecan-oic) C18	Oleic (C18:1)	Linolenic (C18:3)	Linoleic (C18:2)	Arachidic C20 (Eicosanoic)	Any special fatty acid
Soybean	<0.5	7.0-11.0	2.0-6.0	19.0-34.0	5.0-11.0	43.0-56.0	<1.0	
Sunflower	<1.0	3.0-6.0	1.0-3.0	14.0-35.0	>1.5	44.0-75.0	0.6-4.0	Behenic 0.8
Rapeseed		4.9	1.6	33	7.4	20.4		Erucic 23.0
Palm	0.5-2.0	32.0-45.0	2.0-7.0	38.0-52.0		5.0-11.0		

Source: Karmakar et al. (2010).

3. Estimation of used vegetable oil generated by fritter shops in Kolkata

A survey was conducted where used vegetable oil samples were collected from fritter shops in Kolkata in 2012.

The data procured for the type of oil used is given in Table 3.

Table 3. Survey data on generation of used vegetable oil from fritter shops in Kolkata

Serial no.	Vendor	Oil used	Amount of oil used per day (ml/d)	Amount of oil leftover per day (ml/d)
1	V1	Rapeseed oil	5000	300-400
2	V2	Unknown composition	1000-2000	100-150
3	V3	Soybean oil	1500	50-150
4	V4	Soybean oil	3000-4000	300

4. Experimental

4.1. Materials used

In this present study used vegetable oil was filtered. Larger particles like pieces of fried batter and vegetables were removed by passing the oil through a sieve. Then these oil samples were filtered with the help of a piece of cotton kept at the mouth of a funnel. Oil was passed through it into a beaker to remove the finer carbon particles. Methanol of 99% purity was used from Merck Ltd. Sodium hydroxide of 97% purity was used from Merck Ltd.

4.2. Production procedure for biodiesel

Biodiesel derived from used vegetable oil was prepared by first dissolving 0.69g of NaOH in measured quantity of 77 ml CH_3OH without any application of heat. After complete dissolution, 100g of oil was added to this mixture. The reaction was carried out for 90 minutes under reflux at 55ºC. The rpm was maintained at 1000. Molar ratio of oil to methanol was maintained at 1:15. The reaction was carried out in a 500 ml conical flask fitted with a reflux condenser over a magnetic stirrer. The reflux condenser was used to prevent the methanol from escaping. After the reaction was completed, the reaction mixture was allowed to settle overnight in a separating funnel. The knob of the separating funnel was sealed with petroleum jelly and tied with rubber bands to prevent leakage. The mixture formed two distinct layers. The upper phase contained methyl ester (or biodiesel) and impurities like excess catalyst and methanol. The lower phase contained glycerol. Glycerol and crude biodiesel were both collected separately and their volumes were measured. Crude biodiesel was washed with hot distilled water (80ºC). The volume of distilled water used was double the volume of crude biodiesel obtained. Washing was done by pouring distilled water into the crude biodiesel and vice-versa. This was repeated several times. Care was taken that no froth was formed. The mixture was then poured into the separating funnel and kept for half an hour. Biodiesel being lighter formed the upper layer and water formed the lower layer. The pH of water was checked with a pH strip. This process was repeated till the colour of the pH strip was green indicating a pH of 7 and complete removal of NaOH. After washing, the biodiesel was heated to remove any moisture present. All chemicals used were of analytical grade. The experiment was carried out for varying molar ratios of oil to alcohol (1:3, 1:6, 1:12, 1:15) (Table 4). The amount of catalyst used, the reaction temperature and the stirring rate were kept constant.

Table 4. Experimental data

Sl no.	Mass of oil (g)	Molar ratio of oil to alcohol	Mass of catalyst (g)	Mass of biodiesel obtained (g)	Yield of biodiesel (%)
1	100	1:3	0.69	80	80
2	100	1:6	0.69	84	84
3	100	1:12	0.69	88	88
4	100	1:15	0.69	94	94

4.3. Estimation of properties of biodiesel prepared from used vegetable oil

Density of biodiesel was measured in the beam balance with a specific gravity bottle. Flash point of biodiesel was measured with the help of Pensky Marten Closed Tester. Kinematic viscosity at 30ºC was measured with the help of Ostwald viscometer with water as the reference liquid. Calorific value was measured with the help of Bomb calorimeter (Table 5).

Table 5. Properties of biodiesel prepared from used vegetable oil

Properties	Values
Density	0.87 g/cm^3
Kinematic viscosity, at 30°C	5.9 centistokes
Calorific value	7816 kcal/kg
Flash point	179ºC

5. Results and discussion

The most relevant variables in the process of transesterification are reaction temperature, molar ratio of oil to alcohol, amount of catalyst used and the stirring rate (rpm). In this particular procedure it was seen that as the molar ratio of oil to alcohol was varied from 1:3 to 1:15 the percentage of yield of biodiesel increased (Table 4). Yield of biodiesel increased as the amount of alcohol used was increased. The reaction temperature was kept constant at 55ºC. This temperature was not increased further as it would have resulted in the loss of alcohol. The amount of catalyst used was kept between 0.5% and 1.0% (weight of catalyst/weight of oil). Both, excess as well as insufficient amount of catalyst may cause soap formation during washing. Less NaOH would result in presence of unreacted feedstock in the crude biodiesel. More sodium hydroxide catalyst compensates for higher acidity, but the formation of soap causes an increase in viscosity or formation of gel. Also it interferes with the separation of biodiesel after washing. The final physical properties of the biodiesel will depend on the properties of the component free fatty acids present. It determines the yield of product derived from the respective raw material. The maximum yield of 94% was achieved using a greater quantity of methanol.

Density is important mainly when the oil is combusted in a CI engine because it influences the efficiency of atomization of the fuel. The biodiesel produced in this study had a density of 0.87 g/cm^3. Flash point of a fuel is the temperature at which it will ignite when exposed to a flame or spark. The flash point of biodiesel is higher than the petro-diesel, which is safe for transport purpose [11]. The flash point was found to be 179ºC. Calorific value of a fuel is defined as the number of heat units liberated by a unit mass of a sample when burned with oxygen in an enclosure of constant volume. The calorific value of biodiesel was 7816 kcal/kg. Viscosity is a measure of a fluid's resistance to flow. Kinematic viscosity of biodiesel was measured to be 5.9 centistokes at 30ºC (Table 5).

The results show that transesterification improves the properties of oil and brings them close to the properties of diesel. The methyl ester of used vegetable oil can be successfully used instead of diesel or in blended form. The colour of biodiesel from used vegetable oil was bright yellow. Used vegetable oil is not that difficult to find and collect, as there are large food companies selling fried items. They need to maintain the quality of food items so the used oil is sold to soap manufacturing companies. This oil can be collected as feedstock for biodiesel. Thus, there will be no competition to food as refined oil is used for cooking.

6. Conclusion

- Used vegetable oil collected from shops selling fritters can be used to produce biodiesel as it is not a food source and is mostly thrown away.
- Maximum yield of biodiesel prepared from used vegetable oil obtained was 94%.

- Fuel properties of biodiesel are comparable to that of diesel.
- Used vegetable oil has good potential as an alternative fuel. But cannot be used directly in the engines because of high viscosity and low volatility.
- The present experimental studies support the fact that methyl ester of used vegetable oil can be successfully used as diesel.
- The cost of production of biodiesel is higher than that of conventional fossil fuel. This is due to the fact that biodiesel is generally produced from refined vegetable oil. The cost of production can be reduced if low cost feedstock is used such as used cooking oil collected from shops selling fritters.

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