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An Approach of Utilizing Restaurant Waste Vegetable Oil for the Production of Biodiesel

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Abstract: The lack of conventional fossil fuels and the increase of the polluting emissions generated by combustion have increased the necessity for alternative fuels, such as biodiesel. Huge efforts have been carried out in recent years in order to develop an alternative fuel from renewable resources. Biodiesel production has received considerable attention in the recent past as a biodegradable and nonpolluting fuel. The production of biodiesel by the transesterification process employing alkali catalyst has been industrially accepted for its high conversion and reaction rates. The use of cooking oil as raw material is a very interesting alternative for the production of biodiesel. Further, to reduce production cost, in the present research, restaurant waste vegetable oil was used as the feedstock. The effects of methanol as solvent to oil molar ratio and reaction time and temperature on the production of biodiesel were investigated. The results indicated that methanol as solvent, 3:1 methanol: oil molar ratio was found to be optimum at 60°C and 400 rpm. Under these optimal conditions, the conversion of free fatty acids to fatty acid methyl esters was found to be 89%. The crucial biodiesel properties of waste vegetable oil are within the American standard test method specifications.

Key words: Chemical process, Biodiesel production, Optimization.

Introduction

Biodiesel refers to all kinds of alternative fuels derived from vegetable oils or animal fats. Biodiesel is produced from the triglycerides conversion in the oils such as those obtained from palm oil, soybean, rapeseed, sunflower and castor oil, in methyl or ethyl esters by transesterification way. In this process the three chains of fatty acids of each triglyceride molecule reacts with an alcohol in the presence of a catalyst to obtain ethyl or methyl esters [1]. The palm oil is one of oilseeds trade more productive on the planet; it is removed between six and ten times more oil than the other as soy, rapeseed and sunflower. Colombia has more than 300,000 hectares planted in palm oil, generating permanent and stable employment for more than 90,000 people [1].

Biodiesel production from vegetable oils has been extensively studied in recent literature reviews. However, the raw material costs and limited availability of vegetable oil feedstocks are always critical issues for the biodiesel production. The high cost of vegetable oils, which could be up to 75 % of the total manufacturing cost, has led to the production costs of biodiesel becoming approximately 1.5 times higher than that for diesel [2,3].

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Nevertheless, the price of waste cooking oils is 2-3 times cheaper than virgin vegetable oils. Consequently, the total manufacturing cost of biodiesel can be significantly reduced [3]. In addition, a similarity in the quality of biodiesel derived from waste cooking oils and from vegetable oils could be achieved at an optimal operating condition [4].

The most popular method of producing biodiesel is the transesterification of vegetable oils. Biodiesel obtained by transesterification process is a mixture of mono-alkyl esters of higher fatty acids. Transesterification is the alcoholysis of triglyceric esters resulting in a mixture of mono-alkyl esters and glycerol and the sequence of processes is shown in Fig. 1. In the alkali process sodium hydroxide (NaOH) or potassium hydroxide (KOH) is used as a catalyst along with methanol or ethanol. Initially, during the process, alcoxy is formed by the reaction of the catalyst with alcohol and the alcoxy is then reacted with any vegetable oil to form biodiesel and glycerol. Glycerol being denser settles at the bottom and biodiesel can be decanted. This process is the most efficient and least corrosive of all the processes and the reaction rate is reasonably high even at a low temperature of 60°C. There may be risk of free acid or water contamination and soap formation is likely to take place which makes the separation process.

It has been recently found that enzymes such

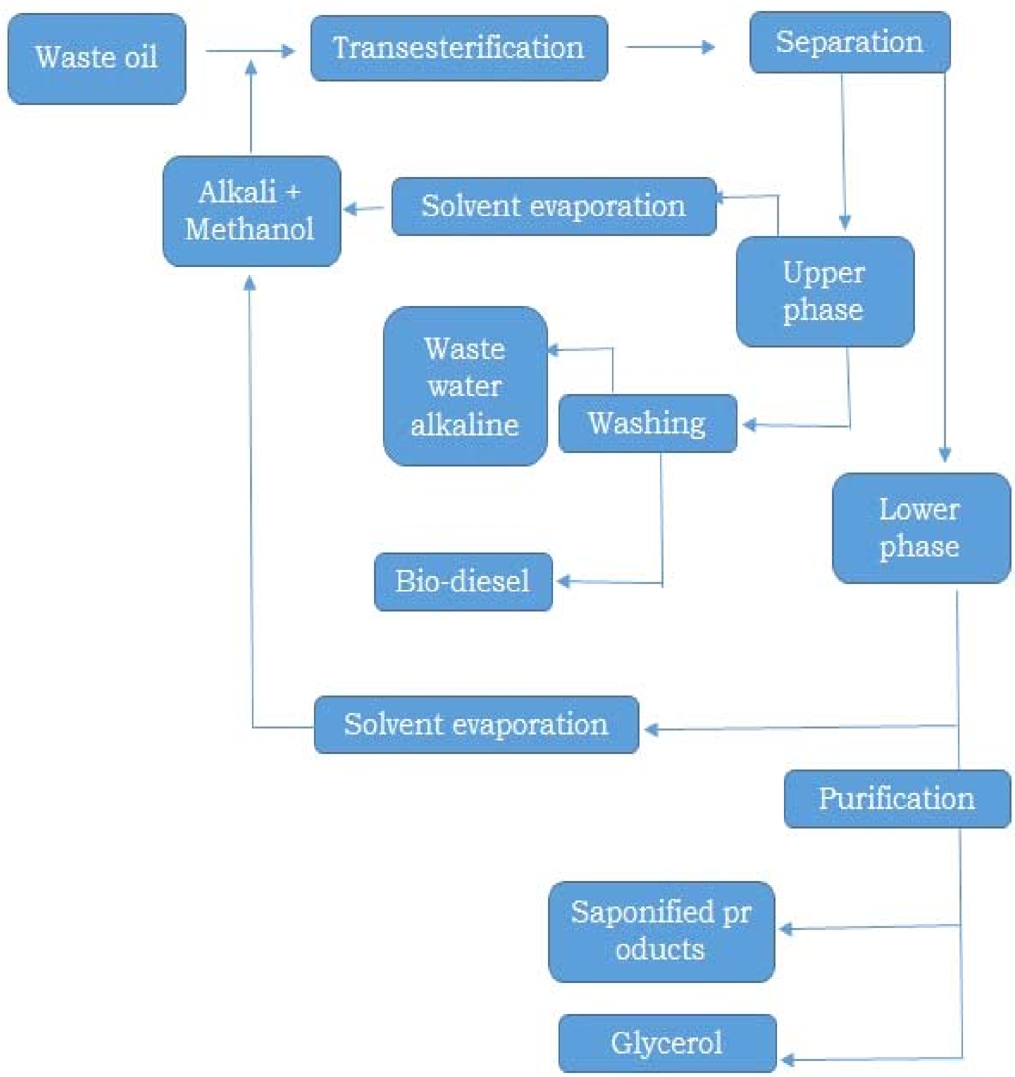

Fig. 1. Production of biodiesel from restaurant waste vegetable oil by using chemical process

as lipase can be used to catalyze the transesterification process by immobilizing them in a suitable spot. The advantage of immobilization is that the enzyme can be reused without separation. Also, the operating temperature of the process is low (50°C) compared to other techniques. Disadvantages include inhibition effects which were observed when methanol was used and the fact that enzymes are expensive [5].

Numerous research projects on the utilization of biodiesel as well as its blending in engines have been done [6,7]. However, most of these were focused on short-term tests on different types of direct injection engines in terms of gas emissions (CO, CO_2, NO_x, and un-burnt hydrocarbons etc.) and engine performances (power output, specific fuel consumption). Concerning these facts, Biodiesel is advised for use as an alternative fuel for conventional petroleum-based diesel chiefly because it is a renewable, domestic resource with an environmentally friendly emission profile and is readily biodegradable [3].

In this research, we have conducted several experiments to produce and compare the biodiesel production from various different waste cooking oil using chemical and enzymatic methods. In this work, the quality of biodiesel from both various different oil has also been analyzed and compared.

Material and methods

Chemicals and reagents

Methanol, ethanol and chloroform were purchased from Merk pharma LTD. Lipase from *P. cepacia* was gifted from Alkem laboratories (India). Potassium hydroxide, sodium hydroxide, sodium sulphate, and phenolphthalein were obtained from Sigma. Vegetable based restaurant waste vegetable oils (mustard oil, soybean oil, castor oil, palm oil) were used for the production of biodiesel.

Chemical process for the production of biodiesel from restaurant waste vegetable oil

The waste vegetable oil was heated at 100°C to remove water. The free fatty acid content of waste vegetable oil was determined using titration, which was below 2 % using the method described by Van Gerpen *et al*.[8]. Therefore, a one-step alkali transesterification was only required. Transesterification of waste vegetable oil was carried out in a temperature-controlled hot plate equipped with a reflux condenser and magnetic stirrer. The biodiesel was produced with the use of KOH under the following conditions: temperature 60°C, reaction time 3 h, methanol to oil mass ratio 30 %, and stirring speed 400 rpm/min. The amount of KOH catalyst was ranging from 0.5 wt% to 1.5 wt % of the waste oils. The catalyst with the highest biodiesel yield was chosen for the study. The mixture of biodiesel, methanol and glycerol was placed in a decanter for settling. The catalyst and glycerol layers were separated and the biodiesel phase was washed thoroughly with water and then heated at anhydrous sodium sulfate added and incubated 100°C to remove water and excess methanol. At the end of the reaction, the catalyst was filtered, washed with distilled water and dried in an oven at 120°C. To test the recyclability the catalyst was reused under the conditions which gave the maximum yield of biodiesel.

Vegetable oil + Methanol Catalyst Biodiesel + Glycerol

Effect of molar ratio of methanol: waste oil and temperature on the production yield of biodiesel. The experiment was optimized to achieve the highest yield of biodiesel by adjusting molar ratios of methanol and waste restaurant vegetable oils as in the ratios of 3:1, 4:1 and 5:1. In addition to this the effect of temperature used (40°C, 50°C, 60°C, 80°C and 100°C) for the biodiesel production was also optimized in order to achieve higher yield.

Effect of KOH catalyst concentration of the conversion of biodiesel

A catalyst plays an important role during the conversion of waste oil into biodiesel. Here we optimized the concentration of KOH (catalyst) to the conversion of biodiesel. Briefly, the reaction was kept at a desired temperature for 30 min, 60 min, 90 min or 120 min and 160 min. The molar ratio of methanol and oil 3:1 while the amount of KOH catalyst was ranging from 0.25 wt %, 0.50 wt % and 1.00 wt % of the waste oils. After a certain time, the mixture was poured into a separating funnel and followed by all similar procedure as mentioned above. The conversation of biodiesel was determined according to Phan *et al.*[9].

Results and discussion

As shown in fig. 2A and 2B as the mass ration of methanol into oil increases the percentage yield of biodiesel decreased. At low methanol to oil ratio, the methyl ester yield is higher. For confirmation, we tried to keep methanol ratio constant with an increased ratio of oils and observed that there was no significant difference in the yield of biodiesel (2B). Higher methanol to oil mass ratio increment leads to the conversion of glycerol and biodiesel back to triglycerides (glycerolysis) and thus the biodiesel yield decreases [10]. Similar findings were observed by Modiba *et al.*[11].

In addition to this, Fig. 3 shows the effect of temperature me on the transesterification of waste vegetable oil, with methanol to oil mass ratio. At lower temperature, the amount of methyl ester from waste vegetable is higher, as the transesterification period is less prolonged and the biodiesel yield increases significantly. However, at a higher temperature as the transesterification time increases the biodiesel yield reduces to a greater extent. Loss of methanol at higher temperature above 60^{o}C (boiling point) due to evaporation could also reduce the biodiesel yield [12].

Felizardo *et al.*[13] revealed that the optimum concentration of sodium hydroxide was 0.6 wt % [13]. This value was much lower than the finding of

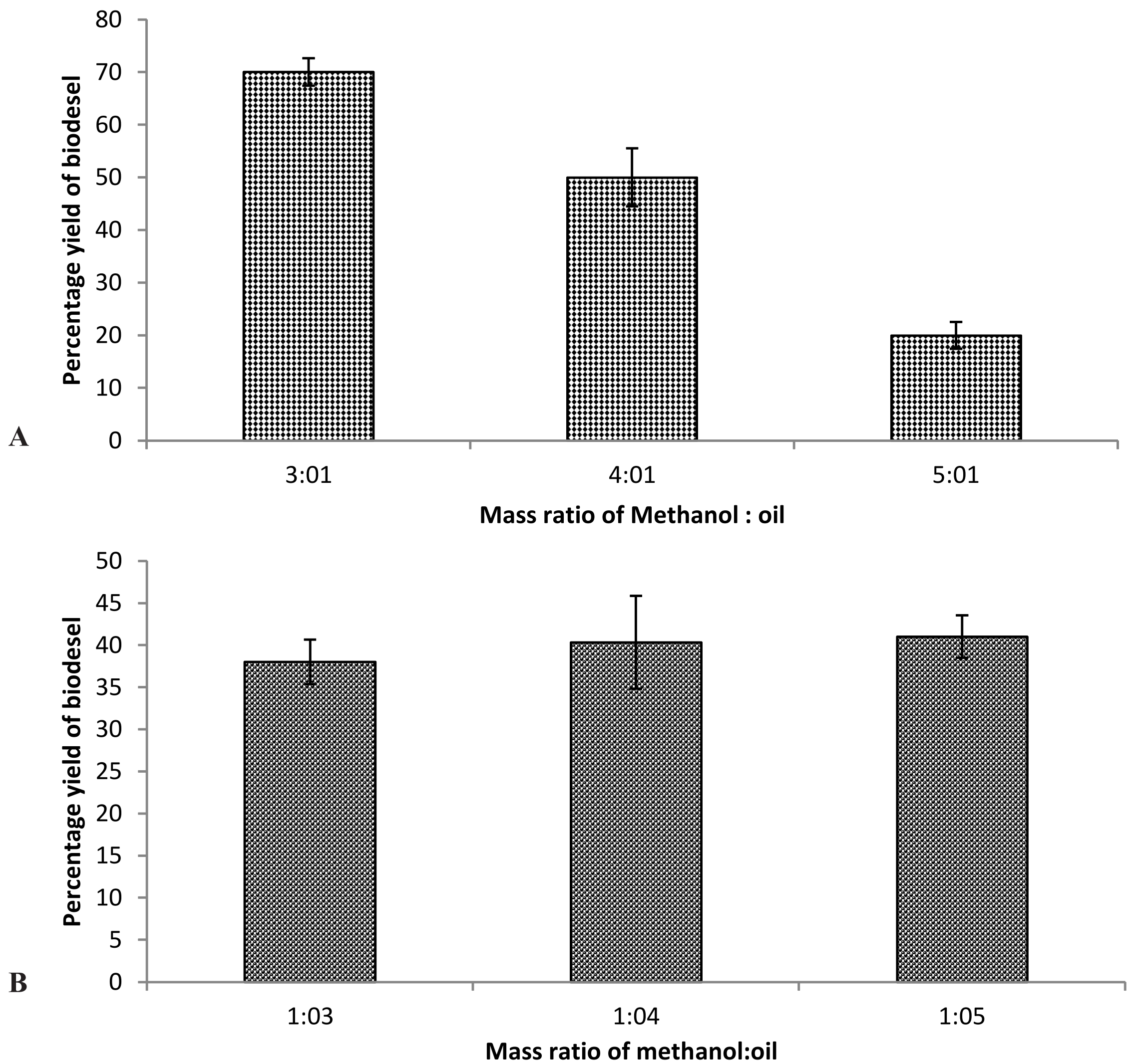

Fig. 2. Effect of mass ratio of methanol: oil on the percentage of biodiesel produced.

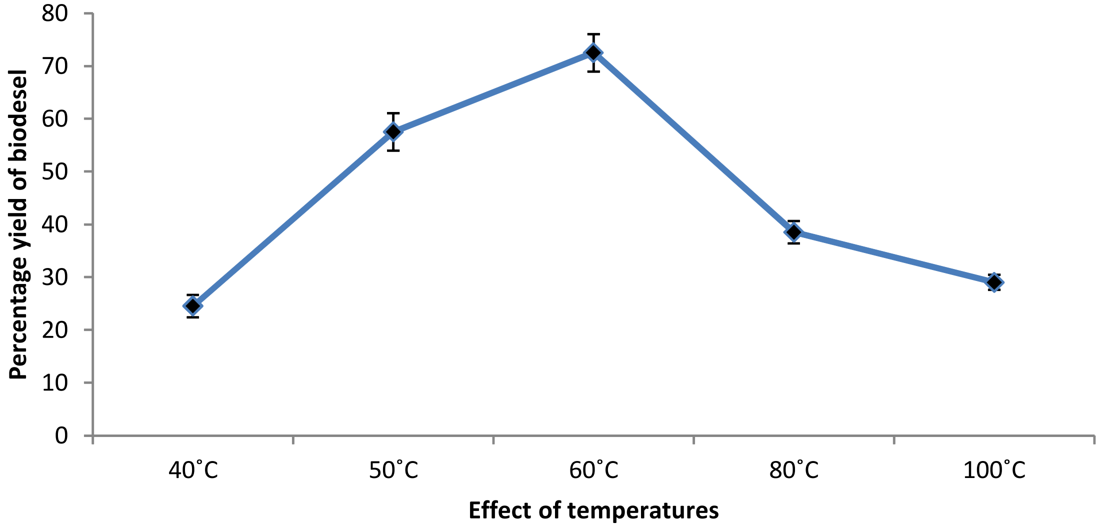

Fig. 3. Effect of temperature on the percentage of biodiesel produced

Georgogianni *et al.*[14]. Leung *et al.*[15] also studied the effect of NaOH concentration on biodiesel derived from neat Canola and used frying oil [15]. It could be concluded that the concentration of alkali catalyst is strongly dependent on the type of oils used. Considering data from literature reviews, the concentration of KOH was tested in a range of 0.25-1.0 wt % of waste oils. Fig. 2 shows the effect of concentration of KOH on the conversion at the methanol/ oil ratio of 5:1. Increasing KOH concentration from 0.25wt % to 1.0 wt % increased the conversion. It was 74 % and 89 % at 0.5 wt % KOH and 1.0 wt % KOH, respectively during 150 min (Fig. 4). The optimum concentration of KOH in this study was the proximate closer to the finding of Felizardo *et al.*[13]. However, it was slightly lower than that from other research [16-18]. This was due to the lower free fatty acid content in the waste oil samples. The higher free fatty acid requires an addition of KOH to compensate for this acidity.

Conclusion

The biodiesel fuel production has gained importance for its ability to replace fossil fuels, its environmental benefits and the fact that it is a renewable source of energy. Since the direct use of vegetable oils as biodiesel is impractical, many

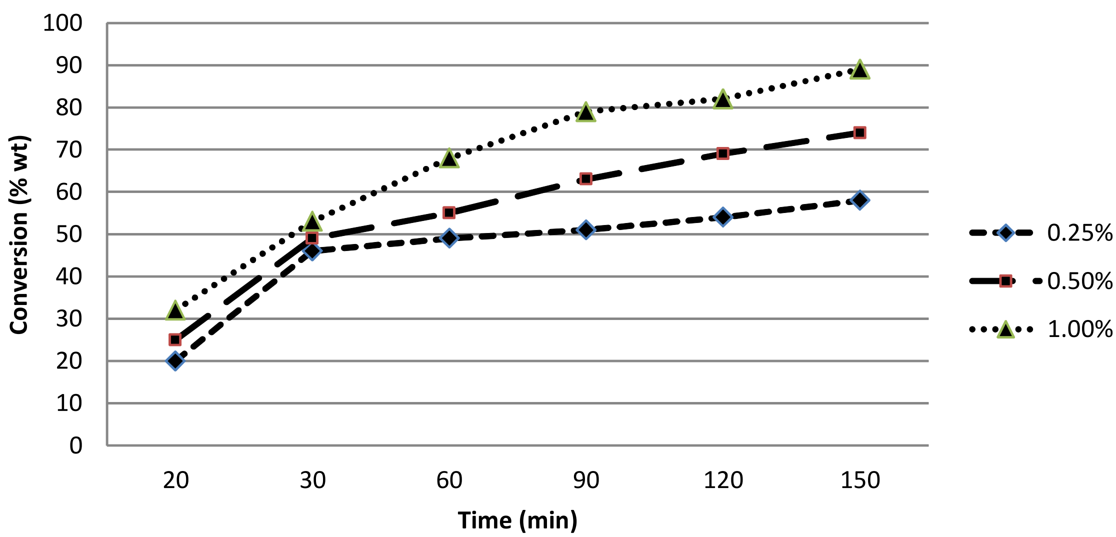

Fig. 4. Effect of KOH concentration on the conversion of biodiesel

processes have been developed to convert them into a suitable form. Combining the whole process with stepwise addition of methanol, and purification with water, significant reduction in the cost the production of biodiesel could be expected. Such novel system is promising for the industrial scale production of biodiesel.

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