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Production of Biodiesel Fuel From Cooking Oil Waste

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Abstract - *Recently biodiesel has become more attractive due to its environmental benefits and the fact that it is made from renewable resources. The cooking oil waste (COW) is tremendous in the restaurants and houses, so the technical disposal of it becomes essential to our life. The reaction takes place by optimum weight ratio of glycerides to alcohol, catalysts, reaction temperature, reaction time which affect the quality of the produced biodiesel. The highest yield of 96% biodiesel were under optimum concentration of 25 %wt methanol, 0.78 wt % of NaOH as catalyst at 70 ^{0}C reaction temperature and 310 rpm stirring speed. The research demonstrated that biodiesel obtained under optimum conditions from COW was good quality and could be used as a diesel fuel which considered as renewable energy and environmental recycling process from waste oil after frying.*

Key Words: *biodiesel; cooking oil waste; alternative fuel; reaction activation energy*.

1. INTRODUCTION

Biodiesel is a nonpetroleum-based fuel defined as fatty acid methyl or ethyl esters derived from vegetable oils or animal fats and it is used in diesel engines and heating systems. According to Diya'uddeen et al, the biodiesel can be defined as a monoalkyl ester of long chain fatty acids derived from a renewable lipid feedstock, such as vegetable oil or animal fat [1].

Thus, this fuel could be regarded as mineral diesel substitute with the advantage of reducing greenhouse emissions because it is a renewable resource. Sodium or potassium hydroxide and sodium or potassium methoxide are used widely as catalysts in the transesterification reaction, as they give high production yield [2-4]. Many studies investigated the availability of animal fats and waste oils for biodiesel production. Bhatti et.al [5] prepared biodiesel fuels from animal fats including beef tallow, mutton tallow and chicken fat. Ma et.al [6] used edible beef tallow as a feedstock for biodiesel preparation. Chung et.al [7] obtained biodiesel from duck tallow using methanol and potassium hydroxide. Naima and Liazid [8] studied waste oils as alternative fuel; and found that that results from using waste cooking oil as fuel for diesel engines showed that the fuel obtained has a higher viscosity and lower calorific value.

A.B.M.S. Hossain [9] investigated biodiesel fuel production from waste canola cooking oil as sustainable energy and environmental recycling process. They stated that the result showed that the optimal combination which gave the highest production of biodiesel in transesterification carried out for 2 hours by using methanol to oil molar ratio of 1:1 catalyzed by 0.5 % sodium hydroxide; and produced biodiesel can be used as fuel in diesel engine. Nor Hazwani A [10] reported that the use of edible vegetable oils and animal fats for biodiesel production has recently been of great concern because they compete with food material- the food versus fuel dispute.

Cooking oils are indispensable in preparation of many meal in the Republic of Yemen and world, therefore there are increasing in the demand. Yemeni people consume an approximately 113,182.64 tons of cooking oil per year [11]. The quantity of COW collected from factories, restaurants, hospitals, bakeries, and hotels in the Taiz city is around 1,799 liters per day. There are many of environmental problems related to cooking

oils waste (COW), for instant which causes occlusion of local sewage networks where organic sediments cannot be removed by water , and hence the additional costs for treatments will be raised. This research has primarily focused on the production of an alternative fuel from the cooking oils waste, and cover a slight part of domestic demand on fuel.

Current, there are a lot of clamours regarding the environment and its sustainability [12]. Thus used domestic waste oil should be considered as a source of fuel for effective mitigation of greenhouse gas emissions as well as for providing environmental benefits and sustainable development via waste conversion to energy. Biodiesel production from waste sunflower cooking oil as an environmental recycling process and renewable energy was evaluated by Hossain et al [13]. This study has provided evidence that waste cooking sunflower oil may be employed as a substantial source of biodiesel as fuel in diesel engines.

2. MATERILAS AND METHODS

2.1. Preparation and Filtration

The frying oil samples were collected from all the restaurants that participated in this research. Filtration is the process by which cooking oil waste as a raw material passes through filtration paper with 0.5 µm mesh after heating the COW up to 40 oC. For faster filtration, pressure vacuum is used in the side hole of the flask (Fig. 2.1).

2.2. Humidity removing from COW

Humidity is water content in the COW as a result of food cooking in the oil. This humidity affects negatively on time of separation process and also it decreases the quality of the final biodiesel produced from COW. For removing it out, the COW must be heated to more than 80 oC using an oven, therefore the bubbles of water come out from the surface of the oil.

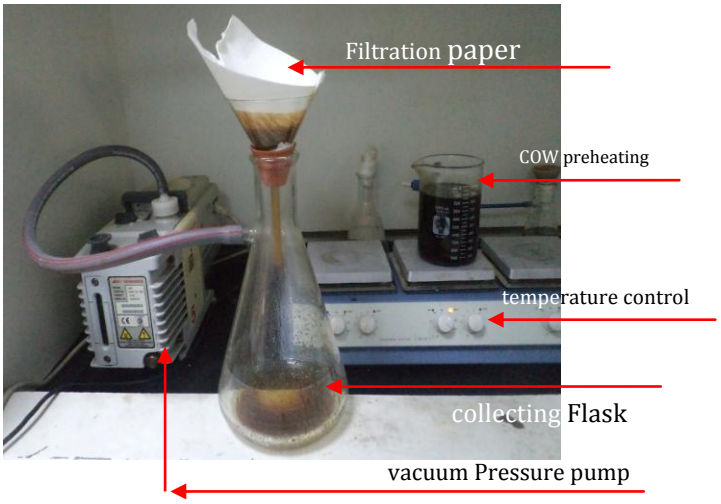


Figure 2.1: Filtration processing

2.3. Water content (humidity) in produced biodiesel

To determine the water content, weight is recorded before heating and then the two equal-sized samples were heated together at the same circumstances for a 20 minutes at a temperature of 100 °C with stirring to steam water. As shown in Eq. (2.1), the water content can be evaluated.

$$WC\% = \frac{w_1 - w_2}{w_1} \times 100 \quad (2.1)$$

Where WC is water content, w_1 and w_2 are the weight of the sample before and after heating respectively.

2.4.Titration

Titration (Fig. 2.2) is a procedure which can determine how much catalyst to be used for the transesterification reaction. The catalyst used in this investigation is sodium hydroxide; and distilled water to balance fatty acid. Isopropyl alcohol as a solvent for the sample of COW, and phenolphthalein as an indicator.

sodium hydroxide solution was prepared by putting 1 g of NaOH in 1000 ml of distiller water; then 1 ml of filtered COW was dissolved by 10 ml of isopropyl alcohol; three drops of the indicator was added to the flask. After that, start falling drops of NaOH solution to the flask till light pink color is clarified , then falling

drops to be stopped and the amount of the solution used has been calculated. fatty acid then can be calculated using following Eq.

$$FA\% = \frac{N \times V \times Mw}{W_{COW}} \quad (2.2)$$

Where FA % is fatty acid percentage, N and V are The normality and volume of sodium Hydroxide, Mw and WCOW are the molecular weight and weight of the COW.

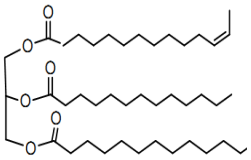
Figure 2.2: titration process

2.5. Transesterification

Sodium methoxide solution (catalyst) first was prepared by reaction of sodium hydroxide with methanol as the following equation:

$$NaOH + HOCH_3 \rightleftarrows H_3CO^- + Na^+ + H_2O \quad (2.3)$$

The reactor comprised was a round-bottomed flask attached to a condenser. The system was kept under reflux and magnetic stirring under the optimum reaction conditions. Molar ratio of oil/methanol = 1: 4.8 and 0.78 wt % NaOH catalyst. The filtered COW is heated up to 60 to 70 oC and kept at this range within reaction , sodium methoxide solution was added to the COW in the reactor and keep the stirring for an hour to obtain the homogeneous mixture. Transesterification process is taken place as the Eq. 2.4



COW

$$+ HOCH_3 \xrightarrow{NaOH} Fuel\ deisel + Glycerine \quad (2.4)$$

2.6. Separation and washing

The homogenous mixture produced by reaction was left from 6 to 8 hours for physically separation. Glycerin precipitated at the bottom of container due to its high density. After separation, the fatty acid aster (diesel fuel), still contains some glycerin and little methanol.

Washing the product by using water as one third of the biodiesel product; heat the water up to 85 oC and also heat the diesel fuel up to 60 o C and stirring the mixtures softly for elapsing 15 minutes to get the rest glycerin out by saponification with water, also washing can rid the rest of methanol and catalyst out of diesel fuel due to the water is good solvent for methanol. The washing can be repeated three time until clean water obtain as shown in Fig.2.3.

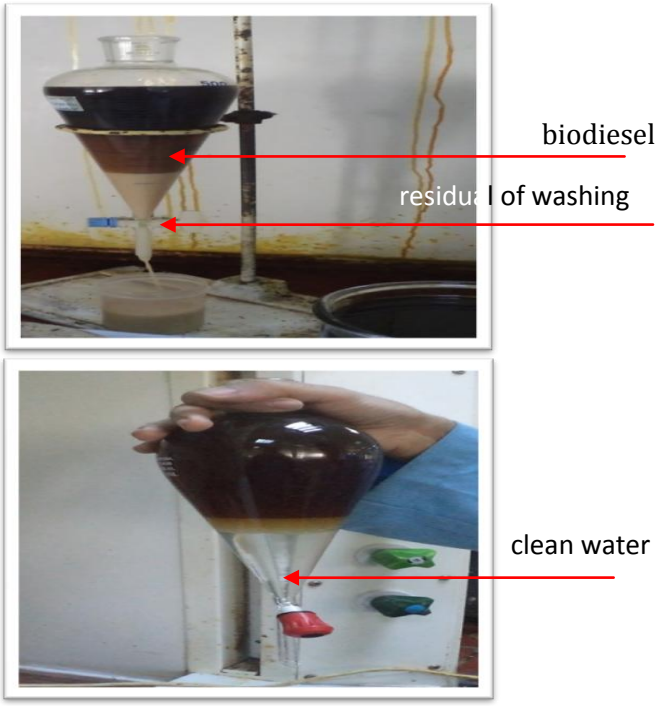


Figure 2.3. Washing process

2.7. Drying

Due to washing the water content is arisen in the biodiesel product which affects the generator motor or vehicles where this water becomes handicap for completing the perfect combustion of diesel fuel. The biodiesel is then heated up to 105 oC for 1.5 h; therefore the water content and the rest of methanol will be removed. At this step, the diesel fuel is ready for chemical, mechanical testing such as combustion efficiency, pour point, cloud point, density, shear stress, cetane number and viscosity to be evaluated whether if it can be candidate to an alternative fuel.

2.8. COW and produced biodiesel testing

For evaluation the produced biodiesel and comparing these results with the standard results, some properties of COW and produced biodiesel were examined. Water content was estimated using gravimetric method. Methanol concentration was measured by evaporation at 75°C. Density at 15 °C and 40 °C was measured using a pyknometre. Dynamic viscosity at 40 °C was measured using a Bookfield viscosimeter therefore the kinematic viscosity was estimated using both the density at 40 °C and the dynamic viscosity. Pour point was measured according to test method of diesel and heating fuels, ASTM D-6371- 99. Figures (2.4. and 2.5) are the viscometer and flash point measurements, respectively.

Figure 2.4. Viscometer measurement

3. RESULTS AND DISCUSSION

3.1. Effect of methanol on biodiesel yield

Methanol is the main material in the reaction which convert COW to biodiesel by transesterification procedure. Fig.3.1 shows the effect of concentration of methanol on the conversion of the COW to the desired product. It is clarity that at the rate of less than 20 w% by weight, the conversion is not complete and the glycerin as by product was not separated easily. Moreover, at the rate of 20 w%, the conversion was 80 w% ; and at the rate of 25 w %, the conversion was complete (97% by wt) but high rate of methanol was not consumed by the reaction.

3.2. Effect of methanol concentration on Flash point

Flash point is the least temperature at which a flash of the fuel vapor is produced during heating, it is an important sign that is measured to show how good a fuel to be stored at normal circumstances, as higher as better the fuel is. The flash point is seemed higher at methanol concentration of 20%w around 156 °C however; beyond this concentration the flash point decreased (Fig. 3.2).

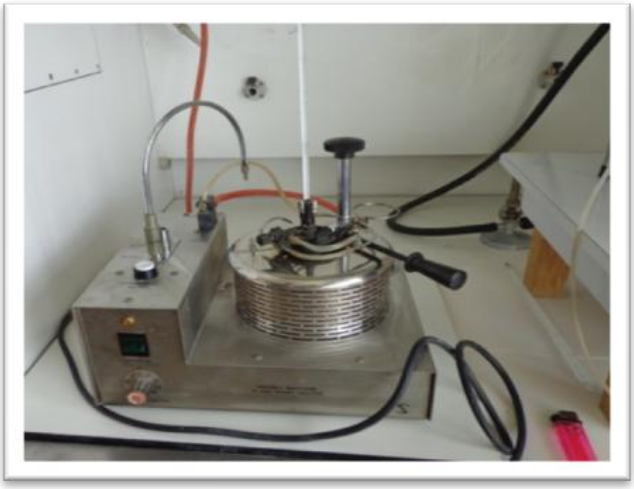


Figure 2.5. Automatic Pensky-Martens Tester

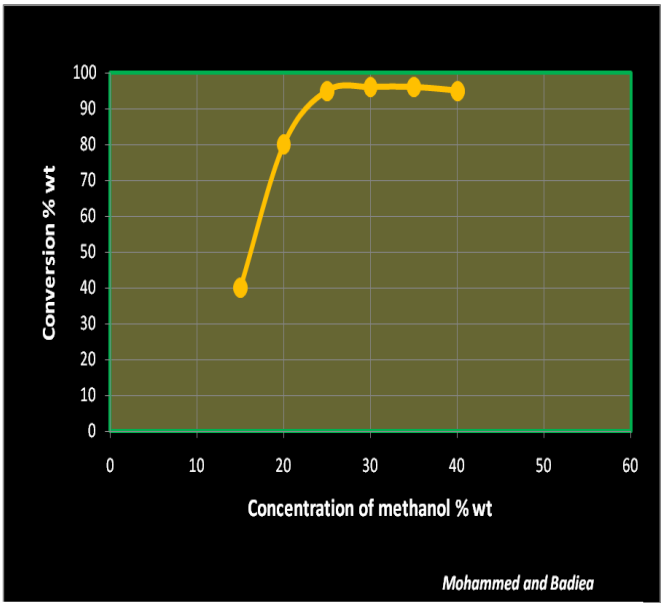


Figure 3.1. Effect of different concentration of methanol on the conversion of biodiesel

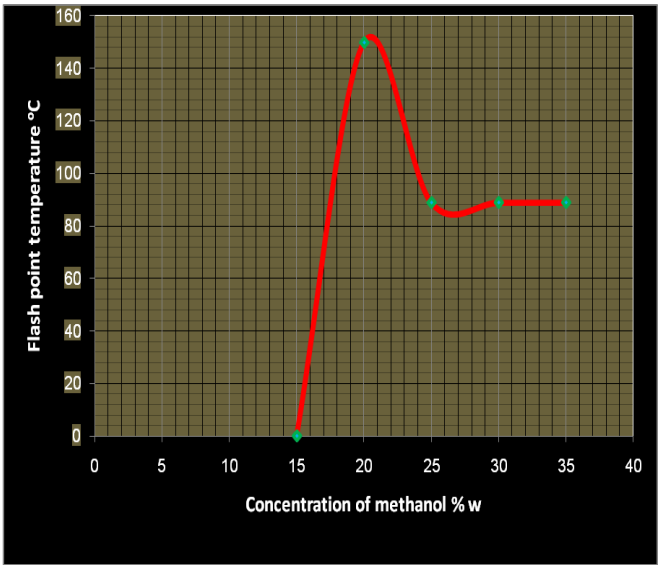


Figure 3.2. Effect of different concentration of methanol on the Flash point of diesel fuel

3.3. Effect of temperature on the reaction and activation energy

The temperature is the main effect of conversion of the reactant to the product. As shown in Fig. 3.3, the conversion was 90 to 96 w % at the temperature range of 60 to 70 °C, as well as above 70 °C the new layer was obtained and thus the reaction was slowest and after on the separation was difficult.

Arrhenius equation is the best way to explain the conversion and how much activation energy at the complete conversion and describes the reaction behavior;

$$k = A \exp\left(\frac{-E_a}{RT}\right) \quad (3.1)$$

Where k is the conversion rate, A is the Arrhenius constant, Ea (J mol^{-1}) is the activation energy, R (J mol^{-1} K^{-1}) is the universal gas constant, and T (K) is the absolute temperature. The larger ratio of (-Ea/(R T)) the smaller rate, as the high temperature and low activation energy favor larger constants , and thus speed up the reaction. Taking the logarithms of the both sides to convert the equation to linearization as following;

By Plotting ln k versus 1/T, the activation energy can be determined (Fig. 3.4). From Eq. 3.2 and Fig. 3.4, the linearization curve fitting is 0.954 which means the plot more acceptable as linearization. The slope is –820 which represents -Ea/R and the intercept is 6.6254 which represents ln A. the value of R is 8.314 J mol^{-1} K^{-1}, so the activation energy for the reaction is 6.82 kJ mol^{-1} ; and the pre-exponential factor A is 754.

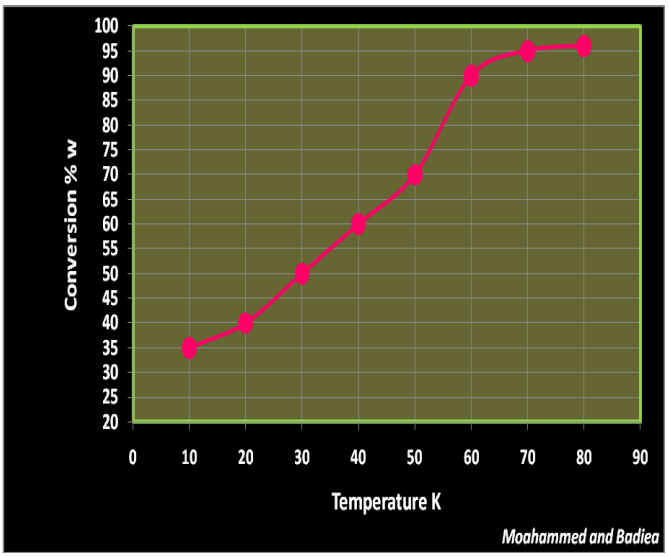


Figure 3.3. Effect of temperature on the conversion percentage

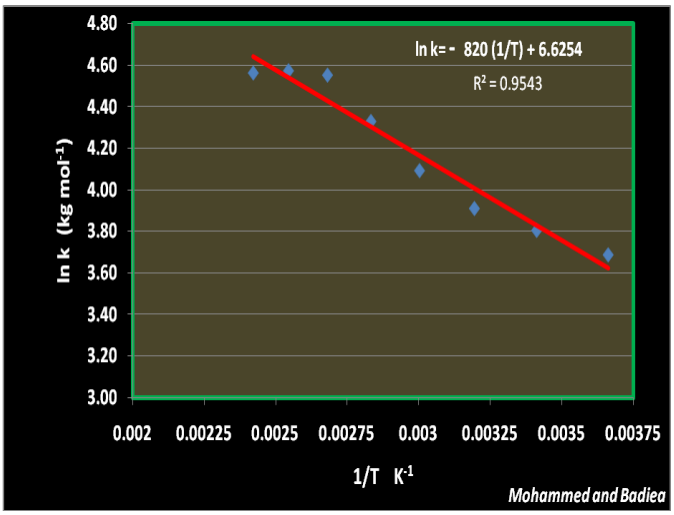


Figure 3.4. plot the inverse temperature versus logarithm conversion

3.4. Parameters for efficiency evaluation

Several parameters have been analyzed by specific method to verify whether the products fulfill the specification of standard methods (ASTM D-6751 & EN 14214); such as viscosity, pour point, flash point, specific gravity, cetane number, combustion efficiency, and ash. All the results are depicted in Table (3.1). It is shown that the biodiesel produced is capable to be replaced instead of the fossil diesel.

4. CONCLUSIONS

The optimum conditions for biodiesel production from COW have been studied. The results showed that the optimal condition of biodiesel produced are 1:4.8 volumetric oil-to-methanol molar ratio, 0.78 wt. % NaOH at 70 ^{o}C reaction temperature.. There was significant effect of concentration of methanol used in the reaction as the optimum concentration was 25 % wt for highest conversion. Activation energy was low which means the conversion would be very acceptable. High temperature of the reaction could lead to create a new layer which may handicap further reaction. Cetane number is 54.5 which means the performance of the biodiesel produced is high. Flash point is 156 ^{o}C is very acceptable comparing to the fossil diesel. This investigation has provided evidence that cooking oil waste can be employed as a substantial source of biodiesel as fuel in diesel engines.

Table (3.1): Parameters for evaluation the produced biodiesel

Evaluation Properties	Units	Produced biodiesel	Fossil diesel
Water content	%	0.046	0.048
Density at 40 ^{o}C	Kg/m^3	8400	8790
Kinematic viscosity	mm^2/ s	2.6	1.9-5.5
Pour point	^{o}C	2	-5 to 9
Flash point	^{o}C	156	165
Cloud point	^{o}C	5	-3 to 12
Cetane number	------	54.4	49.5

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