

Biodiesel Production from waste Oil with Micro-Scale Biodiesel System Under Laboratory Condition

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ABSTRACT:- The aim of this project is to produce biodiesel from waste oil. The use of vegetable oils as diesel fuel started with the invention of diesel engines in the 1900s and is also common in many countries today. The fact that the oils used in biodiesel production are also an important input of the food industry is a limiting factor in production. For this reason, it is aimed to produce biodiesel from waste oil which can not be assessed in food production in this study. The most important contribution of the study to biodiesel researches is the establishment of a small-capacity biodiesel unit in laboratory conditions. The waste oils from the food production facilities of Namık Kemal University (NKU) have been collected and biodiesel has been produced using two different experimental methods. The analyses that determine the quality of the biodiesel samples have been carried out by Energy Agriculture Research Center of Black Sea Agricultural Research Institute in Republic of Turkey Ministry of Food, Agriculture and Livestock. As a result of the research, it has been determined that the biodiesel fuel obtained by the B-1 method using KOH as a catalyst conforms to the standards and can be used with confidence in diesel engines.

Keywords:- Biodiesel, Biomass, Transesterification, Biofuels, Waste Oil

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I. INTRODUCTION

This research focuses on producing of biodiesel from low cost feedstocks such as used cooking oil which is not available for any other evaluation via catalyzed transesterification process.

Biodiesel is a type of fuel that is chemical transformation of vegetable/animal oils and it can be used as fuel in engines either directly or through blending with diesel fuel at certain ratios. The inventor of biodiesel engines, Rudolf Christian Karl Diesel (1858–1913) demonstrated the use of vegetable oils as a substitute for diesel fuel in the 19th century. The direct use of vegetable oils in diesel engines leads to various problems, such as poor atomization of fuel, incomplete combustion with heavy smoke emission, carbon deposition, sticking of oil rings, injector chocking mainly due to the high viscosity of its, low volatility of vegetable oil due to high flashpoint [1].

It is more advantageous to convert the oils to biodiesel in order to overcome these problems. Biodiesel is a renewable fuel produced from vegetable/animal oils and fats, produces lower exhaust emissions than conventional gasoline, requires little or no modification for use in diesel engines, has biodegradability, is superior to conventional petroleum-based diesel in terms of sulphur and aromatic content and flash point, has high performance in case of lubricity properties for biodiesel-fueled engine compared with the diesel-fueled engine. On the other hand, the low calorific value of biodiesel also leads to an increase in consumption, biodiesel fuel releases higher NO_x emission than that of petroleum-based diesel fuel, for long term storage stability of biodiesel is not available due to defects in fuel properties, biodiesel has a relatively poor performance in cold weather because of the low flash point [2]-[4].

Biodiesel, as an alternative fuel of diesel, is described as fatty acid methyl or ethyl esters from vegetable oils or animal fats [5]. The fatty acids are classified according to carbon and hydrogen bonds such as stearic, oleic, linolenic, linoleic etc.

The main process for producing biodiesel is transesterification reaction. The reaction is based on one mole of triglyceride reacting with three moles of methanol to produce three moles methyl ester (bio-diesel) and one mole glycerol. Chemical reaction occurring in biodiesel production stage is shown in Fig.1.

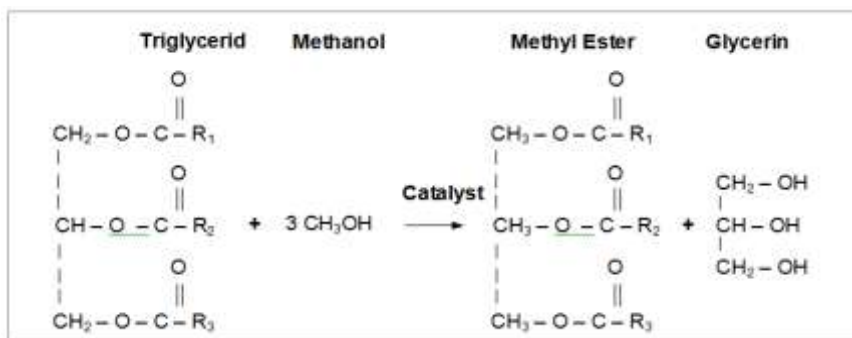


Fig.1: The transesterification process of triglyceride

The basic process schematic of biodiesel production is given in Fig. 2.

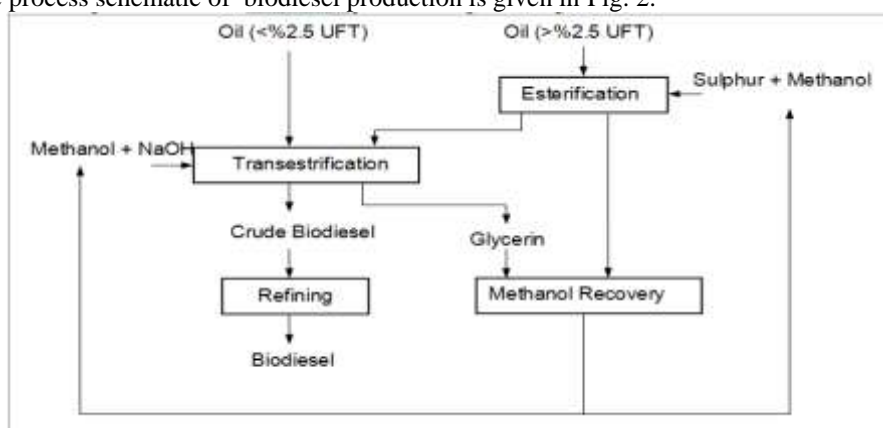


Fig.2: The basic process schematic of biodiesel production

The catalyst is used for speed up reactions. It is not consumed by the reaction, as well as removed with washing water and glycerin. NAOH is widely used as catalyst.

In view of the potential properties, vegetable oils are the main resources for biodiesel production. Biodiesel has been predominantly (more than 95 %) produced from edible vegetable oils (biodiesel first generation) all over the world, which are easily available on large scale from the agricultural industry [6]. Resent research has found that biodiesel is produces from waste oil and algae may provide a viable alternative to future biodiesel production.

The most common that is being developed and used at present is biodiesel, which is produced from seed oils with high content of fatty acid such as sunflower, rapeseed, soy, etc. However, continuous and large scale production of biodiesel from seed oils has recently been of great concern because they are used as food material. This is a major disadvantage, especially for Turkey which is one of the oil importer country. In this context, the purpose of this paper is to produce the biodiesel, which can be converted from waste oil obtained from NKU food manufacturing facilities, in a small-scale biodiesel facility to be installed. The present study is also aimed at determining the parameters affecting biodiesel quality.

II. MATERIAL & METHOD

A. Material

Waste sunflower oil is used as a trial material, which is obtained from the food production facilities of the NKU and filtered for biodiesel production. The filtration process of waste oil is given in Fig.3.



Fig.3: The filtration process of waste oil

A biodiesel unit with a reactor capacity of 1 liter is used to obtain biodiesel from the filtered waste oil. The reactor is made of heat resistant pyrex glass. The reactor is equipped with a temperature control unit that allows the temperature control to be adjusted between $-20\text{ }^{\circ}\text{C}$ and $+120\text{ }^{\circ}\text{C}$, $\pm 0,1$ and a digital controlled mechanical mixer that can be adjustable of speed (200-3000 rpm). The biodiesel production unit is given in Fig.4.



Fig.4: The biodiesel reactor

B. Method

The basic processes in both methods can be explained as feedstock pretreatment, preparation of methanol and catalyst mixture, adding the mixture to the waste oil in the reactor, glycerin removal, washing biodiesel and storage. Two different experiment methods have been applied to compare the effect of catalysts to be used in waste oils. The process steps are described in detail below.

B1 Method

The transesterification of oil is achieved with 120 min of reaction time using KOH as a catalyst at a reaction temperature of $87\text{ }^{\circ}\text{C}$, 6% of catalyst in relation to the oil mass, a methanol to oil molar ratio of 9:1. The preheating of oil at temperature as $122\text{ }^{\circ}\text{C}$ and stirring (at $\sim 3000\text{ rpm}$) is maintained throughout the entire reaction [2],[7]. The preheating phase of the waste oil at the temperature determined in the first method is given in Fig.5.



Fig.5: Preheating phase of waste oil

Methanol and the used KOH catalyst are mixed with magnetic stirrer at 400 d / min . The preparation phase is given in Fig.6.



Fig.6: The preparation phase of (methanol-catalyst) mixture

The oil fed to the reactor is preheated before the catalyst and methanol are added. The methanol and catalyst are placed in the reactor and stirring is carried out during the reaction time. The process is given in Fig.7.



Fig.7: Adding the mixture in the reactor (B1)

After reaction time, the mixture is placed in the separator funnel and allowed to stand. The process time for glycerin to settle down because of high density to 8 hours. The valve of the separation funnel is opened for the separation of glycerin from biodiesel. The separation of glycerin from biodiesel is given in Fig.8.



Fig.8: The glycerin removal process

As the spilled water from the top of the separation funnel passes through the biodiesel it also collects the catalyst and other foreign substances at the bottom. After this process is finished, the valve under the separation funnel is opened to remove water. This process step is given in Fig.9.



Fig.9: Washing biodiesel (B1)

The biodiesel sample obtained after washing process is given in Fig.10.



Fig.10: Biodiesel (B1) sample

B2 Method

The transesterification of oil is achieved with 240 min of reaction time using H_2SO_4 as a catalyst at a reaction temperature of $80\text{ }^\circ\text{C}$, 1.9% of catalyst in relation to the oil mass, a methanol to oil molar ratio of 162:1 and stirring (at $\sim 3000\text{ rpm}$) is maintained throughout the entire reaction. In addition, preheating is not applied in this method [8]. The experiment is started at the reaction temperature without preheating.



Fig.11: Preparation of catalyst and methanol mixture

The H_2SO_4 catalyst and methanol are mixed and prepared as shown in Fig.11. The prepared mixture is added to the waste oil in the reactor as in Fig.12. and stirring is carried out during the reaction time.



Fig.12: Adding the mixture in the reactor (B1)

The subsequent processing operations are the same as in the B1 method, except that the separation time of glycerin. Glycerol complete separation has been achieved in 12 h. The biodiesel produced by the B2 method is shown as in Fig.13.



Fig.13: Biodiesel (B2) sample

Properties of Biodiesel

The physical and chemical properties of biodiesel are identified according to standards [9] as follows to compare the quality of biodiesel obtained by two different methods.

- Efficiency
- Density
- Kinematic Viscosity
- Flash Point
- Carbon Residue
- Water Content
- Copper Strip Corrosion
- Asid Value
- Iodine Value
- Sulfur Content
- Cloud Point
- Cold filter plugging point

III. RESULTS & DISCUSSION

Biodiesel experiments are repeated two times both B1 and B2. The biodiesel samples have been carried out by Energy Agriculture Research Center of Black Sea Agricultural Research Institute in Republic of Turkey Ministry of Food, Agriculture and Livestock. The results of the analysis are as shown in Table II.

Table II: The Physical and Chemical Properties of Biodiesel Experiments

Properties	Unit	European Committe for Standardization		Biodiesel Experiments	
		Min	Max	B1	B2
Efficiency	%	-	-	93	86
Density, 15°C	kg/m ³	860	900	888,1	892.9
Viscosity 40°C	mm ² /s	3,5	5,0	5,64	7,05
Flash Point	°C	120	-	>120°C	>120°C
Carbon Residue (10% distillation residue)	% (m/m)	-	0,3	0,33	0,61
Water Content	mg/kg	-	500	424,6	385,4
Copper Strip Corrosion	50°C, 3h	-	1	1a	1a
Asid Value	mgKOH/g	-	0,5	0,18	0,18
Iodine Value	-	-	120	119,49	119,28
Sulfur Value	mg/kg	-	10	3,6	1,4
Cloud Point	°C	-	-	2°C	6°C
Cold Filter Plugging Point	°C	-20°C	0°C	-6°C	-3°C

Efficiency of Biodiesel production is expected to be over 90%. This value is 93% in the first method (B1) and 86% in the second method (B2). The first method has the desired value in terms of efficiency. Density is the measure of the fluidity of biodiesel. The density is expected to be between 860-900 kg / m³. This value was between the desired values of 888.1 and 892.9 kg / m³ respectively in B1 and B2 methods. Viscosity is one of the most important characteristics of biodiesel. High viscosity fuel causes poor atomization, bad combustion, clogging of the injectors and carbon build-up in the segments. This value should be between 3.5-5 mm²/s for biodiesel. However, the upper limit is accepted as 6 mm²/s in some literature [10]. For this reason, the viscosity value obtained in the B1 method can be accepted within the limit metrics.

For biodiesel with a high carbon residue, it impedes the efficient operation of the engine, which results in increased deposits in the combustion and exhaust spaces. While the accepted value in the European Standards is a maximum of 0.3%, some researchers indicate that a maximum of 0.4% of this value would be sufficient [10]. This value was 0.33% in the first method (B1) and 0.61% in the second method. The carbon stock value obtained in the method B1 is acceptable. The water content in both methods remained below the maximum value at 424.6 and 385.4 ppm, respectively. Copper strip corrosion values are at the desired values in both methods. Acid value is 0.18 mgKOH/g in both methods. The value is below the desired maximum value (0.5 mgKOH/g). The iodine value is a measure for the unsaturation. Iodine values are (119,49 and 119,28) slightly lower than the maximum value (120). Sulphur content in diesel fuel is limited to 10 ppm. Sulfur content values are below the desired maximum value in both methods (3.6 and 1.4 ppm, respectively) The cloud point depends on the properties of the raw material from which biodiesel is obtained. For example, when measured by ASTM D2500 standards, the temperature of the biodiesel obtained from rapeseed oil is -3 °C, while the value of food-grade frost is 19 °C [10]. In this study, biodiesel was obtained from waste oil using two methods, the cloud point are 2 °C and 6 °C respectively.

The cold filter plugging point is crucial to working in cold weather. While this value should be -20 °C in winter months, 0 °C in summer is enough [10]. The cold filter plugging point was -6 °C in the B1 method and -3 °C in the B2 method. The value obtained in the first method is lower than in the second method. It is possible to operate B1 biodiesel in cooler weather, but there is a risk that the obtained biodiesel will be used in very cold winter months.

IV. CONCLUSIONS

The optimum reaction conditions are determined to obtain the most appropriate conversion to standards according to the analysis carried out in this study. The main conclusions drawn are that the best conversion is reached when the methanol:oil molar ratio is 9:1, the reaction time is 120 min at 87 °C with preheating process at 122 °C and the catalyst (KOH) mass is 6% in relation to the oil mass used in B1 method. It appears that the experimental data derived from B2 method exceeded limit of viscosity and carbon residue. For this reason, direct use of biodiesel or mixing with diesel fuel would be inconvenient. The one of the most important contribution of this study to biodiesel researches is the establishment of a small-capacity biodiesel unit in laboratory conditions.

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