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Biodiesel Making and Experimented Results from Waste Cooking Oil, in Mongolia

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ABSTRACT

Biodiesel is a nontoxic and biodegradable alternative fuel that is obtained from renewable sources. Waste cooking oil is one of the economical sources for biodiesel production, because it is widely available and low in cost. Waste cooking oil contains more free fatty acids (FFAs) than biodiesel, which creates challenges during the transesterification process in producing biodiesel. The biodiesel titration process explained here gives a quick and simple way of determining the FFA content of the oil being tested and a means of identifying how much extra potassium hydroxide or sodium hydroxide is necessary to add to the reaction. In this instance, we used 1 liter of methanol to 5 liters of waste cooking sunflower oil, and 3.5 g of NaOH per liter of oil, with an additional 1.5 g of NaOH based on the results of the titration process. Therefore, we used a total of 5 g of catalyst for 5 liters in the reaction. Laboratory test results for the biodiesel derived from waste cooking oil indicated low sulfur content and cetane number, but much higher viscosity compared with conventional diesel fuel. According to the results of the experiment, the optimum application for this product came from using a B20 mixture of diesel and biodiesel fuel, with an overall increase in fuel consumption of 6.5%. It means this mixture fuel is practical for use.

Keywords: Waste cooking oil, Biodiesel, diesel engine, fuel consumption.

INTRODUCTION

The need for energy is increasing continuously, because of increases in industrialization and population of the world. Decreasing fossil fuel reserves, and the atmospheric pollution created by petroleum-based fuels, have necessitated alternative sources of energy. One of the most promising areas for future growth in alternative energy is biodiesel fuel for use in major industrial sectors and public transport.

The production of biodiesel from waste cooking oil is one of the better ways to utilize it efficiently and economically. Waste cooking oil, which is much less expensive than pure vegetable oil, is a promising alternative to vegetable oil for biodiesel production. Biodiesel is an alternative fuel for diesel engines made from plant oils, waste cooking oils, or rendered animal fats. As it is derived from biological sources, either directly from clean vegetable oils or indirectly from animal fats or waste cooking oils, it is a truly renewable energy source [1].

Biodiesel is defined as the monoalkyl esters of long chain free fatty acids derived vegetable oil, animal fat or waste cooking oils for use in compression-ignition diesel engines. This specification is for pure (100%) biodiesel prior to use or blending with conventional diesel fuel. The advantages of biodiesel are that it is a renewable and biodegradable biofuel that produces less harmful emissions to the environment than those produced by fossil fuels.

Biodiesel can be designated as B100 when pure, or when blended with with diesel fuel, designated as BXX, where XX represents the percentage of biodiesel in the blend. The most common ratio is B20

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(20% biodiesel and 80% petroleum diesel) decreases emission constituents of hydrocarbons, carbon monoxide, and particulates by 21.1, 11.0, and 10.1% respectively, and increases NO_x by 2.0%. When 100% biodiesel is compared with petroleum diesel, there is a 67% decrease in hydrocarbons, a 48% decrease in CO and particulate matter, and a 10% increase in NO_x [8].

We derived the biodiesel in this process from pure sunflower oil and waste cooking oil at the Mongolian University of Life Sciences` laboratory, the first time this was achieved in Mongolia.

MATERIALS AND METHODS

Waste Sunflower Cooking Oil

Sunflower oil has been taking over 90 percent of the national market for vegetable oil in Mongolia.

Waste cooking oil is one of the most economical sources for biodiesel production, because of its availability and low cost. Waste cooking oil contains a high proportion of free fatty acids (FFAs). FFAs offer challenges during the transesterification reaction for making biodiesel. This would be waste vegetable oil for the average producer at home, and may be collected for free in most restaurants. We used 100 liters of waste sunflower cooking oil in this study.

Alcohol

Methanol is most frequently used in the application of recycled vegetable oil. When processing new oil, it is possible to use ethanol, but ethanol is more difficult to handle. Because of this, methanol is used in this study.

Transesterification

Transesterification is the reaction of fats or oils with alcohols to form biodiesel esters and glycerol. Methanol is most commonly used in the transesterification process because of its relatively cheap price compared to other alcohols.

Common alkaline catalysts are Sodium hydroxide (NaOH) and Potassium hydroxide (KOH). A catalyst is required to improve the reaction rate and yield. Both KOH and NaOH may be used. The advantage of KOH is that the residual glycerine is much less toxic than when NaOH is used. In that case, it is even possible to process the glycerine into artificial fertilizer. KOH is available in methanol, as well. However, an advantage of NaOH is that accessible and inexpensive as KON and it is easy to handle. That is why we used it in this manual.

Titration

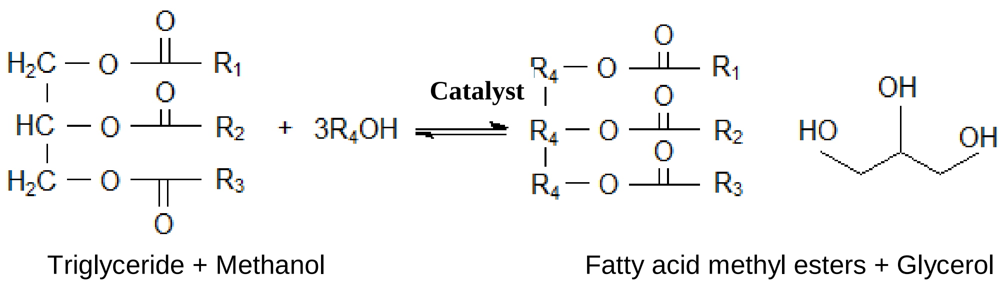
The biodiesel titration process explained here provides a quick and simple way of determining the FFA content of the oil being tested and will identify straight away how much extra Potassium hydroxide or Sodium hydroxide to add.

If new vegetable oil is processed, then it will require a starting quantity of 5 g of NaOH or 7 g of KOH per liter of oil. We used this as the initial amount and calculated the extra required for the solution. Therefore, we prepared 1.5 g extra catalyst solution per 5 liters of oil used.

Biodiesel Production Process

Biodiesel production is completed through the transesterification reaction, which consists of three consecutive and reversible reactions. First, the triglyceride is converted into diacylglycerol, and running at monoglyceride and glycerin. In each reaction one mole of methyl ester is released (Fig 1.).

Overall transesterification reaction



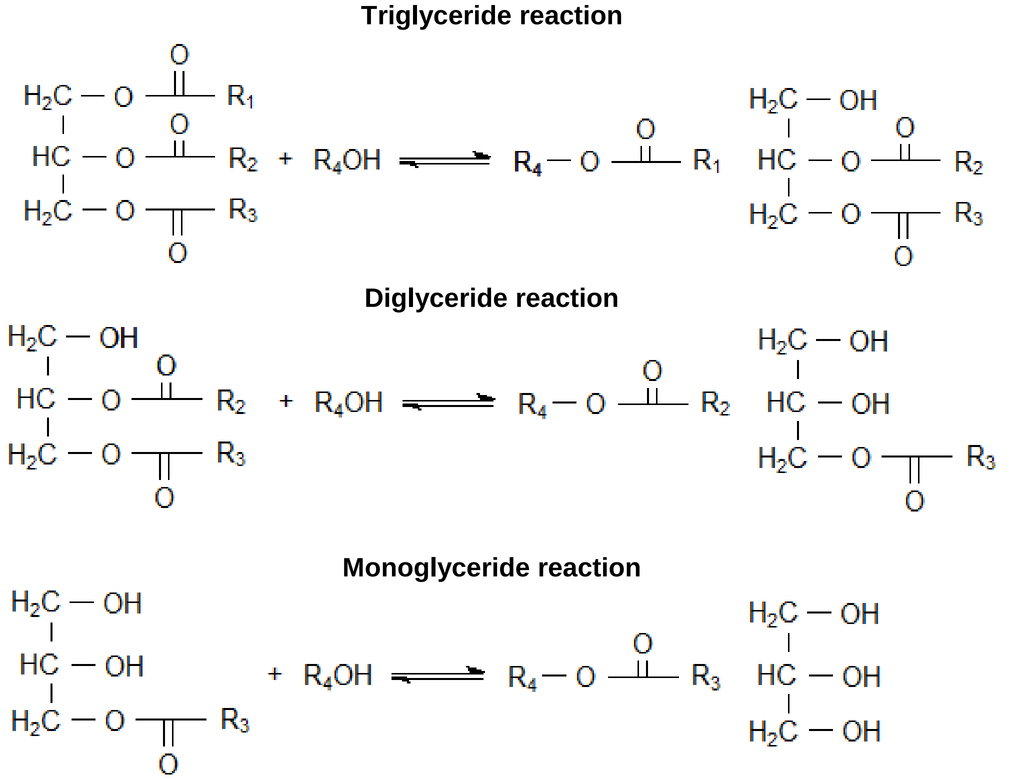


Fig1. *Stage of the transesterification reaction*

Figures 2 and 3 show the secondary reactions that may occur: the transesterification reaction and the neutralization reaction of free fatty acids.

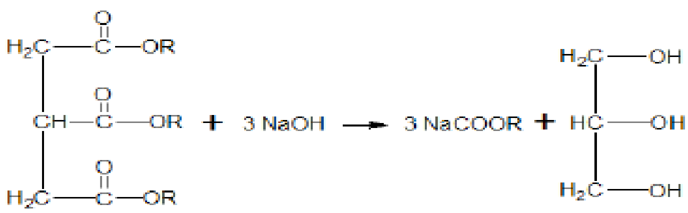


Fig2. *Transesterification reaction*

$$RCOOH + NAOH \rightarrow R - COONa + H_2O$$

Fatty acid Sodium carboxylate

Fig3. *Neutralization reactions of free fatty acids*

We used 1 liter of methanol to 5 liters of waste cooking sunflower oil, and 3.5 g of NaOH per liter of oil and then added 1.5 g of NaOH as a result of the titration process. Therefore, we used 5 g of catalyst for 5 liters in the reaction.

A monitored research tractor was used to measure the performance of the diesel and biodiesel fuel. Using standard procedures as listed in Table 1, physical and chemical properties such as cetane number, density, viscosity, cloud and pour points and flash point were defined.

Here, pure petroleum diesel and three biodiesel blends were used: 100% diesel, 80% diesel with 20% biodiesel, 50% diesel with 50% biodiesel, and 100% biodiesel.

Table1. *Standard test methods used to characterize methyl esters*

Properties	Method
Fatty acid composition	AOCS method
Density	ASTM D4052 (ASTM 2005a)
Viscosity	ASTM D445 (ASTM 2004)
Cetane number	ASTM D613 (ASTM 2002a)
Pour point	ASTM D 97

RESULTS AND DISCUSSION

The objective of this study was to compare fuel properties, fuel consumption and some fuel emissions of biodiesel from waste cooking oil with petroleum diesel fuel.

First, we defined properties of petroleum based diesel fuel and pure oil biodiesel, which were used in Mongolia. Laboratory test results for the biodiesel derived from waste cooking oil, demonstrated low sulfur content, and cetane number, but viscosity was very high compared with conventional diesel fuel. The viscosity of biodiesel derived from waste cooking oil was as much as 6.1 units or 3.6 times higher, which could help to improve the lubrication properties, to reduce abrasion of metal components, and to increase stock of an engine metal.

The properties of petroleum based diesel, biodiesel from clean sunflower oil and biodiesel derived from sunflower waste cooking oil are given in Table 2. It can be seen clearly that B100 had very low sulfur content compared with petroleum diesel. The cloud point of the various methyl esters ranged from -5 to 9^{0}C. The pour point of methyl esters ranged from -35 to -3^{0}C.

Table2. *Compared properties of petroleum based diesel with biodiesel derived waste cooking oil*

Properties	unit	Diesel fuel based petroleum	Biodiesel from clean oil	Biodiesel from waste oil
Density	kg/m^3	814	865	888
Viscosity	mm^2/s	2.331	4.862	8.432
Cetane index	-	47	59	49
Pour point	^{0}C	-35	-6	-3
Cloud point	^{0}C	-5	+5	+9

Second, we checked biodiesel consumption with petroleum diesel fuel. The result of the experiment was increased fuel consumption, by 16.3% in the 50% blend and with pure biodiesel by 32.6%. Fuel consumption for 20% biodiesel was the lowest compared with the 50% blend, and 100% biodiesel under light loading of the tractor engine. This suggests that the B20 mixture fuel is most practical and adequate for use.

The limits of biodiesel fuel consumption of the tractor diesel engine compared with conventional diesel are shown in Table 3.

Table3. *Fuel consumption of diesel engine*

Fuel types	Fuel consumption		Difference (%)
	l/h	kg/h	
Diesel fuel	7.17	5.97	100%
B20	7.64	6.65	6.5%
B50	8.34	7.92	16.3%
B100	9.51	8.63	32.6%

CONCLUSIONS

During the study, the following results have been observed.

1. The viscosity of biodiesel derived from waste cooking oil is 3.6 times more than the viscosity of standard petroleum-based diesel fuel. Although it has a positive impact on improving lubrication, it cannot be used alone (B50 or B100) because it can freeze easily in the cold conditions common in Mongolian winters.
2. When the viscosity of biodiesel derived from waste cooking oil is excessive, it injects into the cylinder as droplets instead of particles or mist. This reaction increases the fuel consumption because of incomplete combustion. Therefore, results of our study showed that when a diesel engine runs with biodiesel at more than a B20 mixture, it increased the fuel consumption by 16.3% for B50 and 32.6 % for B100.
3. According to this study, the Cetane number of biodiesel fuel from derived waste cooking oil was 2.0 units; it was higher than petroleum diesel fuel. It means that the period of combustion is reduced, fuel burned completely, and the amount of toxic gases decreased.

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