

The transesterification of waste cooking oil to biodiesel

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Abstract: At present, the challenges of energy demands and preserving the earth's climate are playing a prominent role in energy and fuel researches.

The transesterification of waste cooking oil to biodiesel not only solves the problem of waste oil treatment but also replaces partially or fully nearly one thousand million tons of diesel used annually by the world. In the present work, 94% of waste cooking oil sample is converted to biodiesel. The specifications of synthesized fuel are tested and compared with Iraqi diesel and other biodiesels. The economic side was also studied comparing the cost of producing one liter of biodiesel from the cooking oil used with the price of a liter of domestic diesel fuel.

Keywords: waste cooking oil, transesterification, biodiesel, diesel, earth's climate.

1. Introduction

The availability of energy sources is the most serious threat to the development of mankind and nations superiority. The high rate of energy consumption leads to decrease in traditional energy sources and increase in the pollutant emissions which harm the ozone layer. This difficult challenge drives the decision makers, experts and researchers to think by decisive and successful solutions. Waste oil ester or the biodiesel from waste cooking oil is a promising renewable source of energy to supplement the conventional diesel and solve the polluted emissions crisis.

Biodiesel is a non-petroleum based diesel fuel which consists of the mono alkyl esters of long chain fatty acids derived from renewable lipid sources. Biodiesel is typically produced through the reaction of a vegetable oil, waste oil and animal fat with methanol in the presence of a catalyst to yield glycerin and biodiesel (chemically called methyl esters) [William & lloyd].

Biodiesel runs in any conventional diesel engine and no engine modifications are necessary to use biodiesel. Also, Biodiesel dramatically reduces harmful emissions that cause environmental problems such as global warming, acid rain and smog. Biodiesel reduces CO₂ emissions by over 78% compared to petroleum diesel. Even blended with petroleum diesel, biodiesel significantly reduces emissions[Gertz]. Furthermore, the plants used to make biodiesel feedstock absorb more CO₂ as they grow than the biodiesel produces when it is burned [Duraid at el.]. The using of waste oil as a feed stock for biodiesel production

not only provides a new source of energy but also addresses the pollution by the waste oil itself and greenhouse problems as well. In the present work, the local (Iraqi) waste cooking oil is collected, filtered and reacted with NaOH and the methanol at different concentrations and wasteoil heating temperatures. The ratio of 1 liter waste cook oil, 4 gram of sodium hydroxide , 130 ml methanol and 60°C waste oil heating temperature gave the higher ratio of synthesized biodiesel. 94% by volume of biodiesel and 6% of glycerine are produced. Also, the cost is calculated. The price of one liter of biodiesel is cheapest than the price of local conventional diesel.

2. Waste oil and Frying Process

Food frying oil named usually as waste oil. During frying process, oil is continuously or repeatedly subjected to high temperatures in the presence of air and moisture. Three essential degradation reactions occurs under these conditions are [Stevenson at el, Cho and Min]:

- Hydrolysis causing from the moisture content of fried food. This reaction produces free fatty acids (FFA), mono- and diglycerides.
- Oxidation causing from the contact with oxygen. Reaction products are oxidized monomeric, dimeric and oligomeric triglycerides and volatile materials such as aldehydes and ketones.
- Polymerization causing from these two reactions, and high temperatures. This reaction produces dimeric and polymeric triglycerides with ring structure.

Because of these degradation reactions mentioned above, a number of physical and chemical changes occur in frying oils including increase in viscosity, density, FFA content, total polar material (TPM), polymerized triglycerides, and decrease in smoke point, the number of double bonds, etc. If the frying process is continued, these materials will undergo further degradation and finally the oil will not be appropriate for frying [M. Rakib Udden at el]. The frying oil has to be discarded. Since all degradation products are of polar character, TPM content of frying oil is a good indicator of its degradation level. Thus, in many countries, TPM content of frying oil has been legally accepted as the limit value to decide discard it or not. For example, in Turkey, TPM content of frying oil must not exceed the top

level of 25% [Aladedunye and Przybylski]. In addition to TPM, as the oil deteriorates, some changes in its physical and chemical properties occur. For instance, during frying, oil's double bonds are ruptured and so its fatty acid composition changes, FFA level and saturation degree increase [Knothe and Steidly]. The change in the fatty acid composition influences some oil properties such as iodine value, viscosity, density, heating content. Thus, these properties can also be used to monitor the quality of the frying oil.

3. Waste cooking oil as a feedstock for biodiesel source

In the early 20th century, the diesel engines run by vegetable oil then the conventional diesel took the lead of diesel engine fuel. Biodiesel is merely different than its bio oil source in properties. Recently, raw vegetable oils and animal fats have increasingly been substituted for "processed" biodiesel meeting established specifications. The U.S. Department of Energy has stated that, "Raw or refined vegetable oil, or recycled greases that have not been processed into biodiesel, are not biodiesel and should be avoided" [E.M.A].

The use of raw, unprocessed vegetable oils or animal fats in diesel engines – regardless of blend level – can have significant adverse effects and should not be used as fuel in diesel engines. Raw or refined vegetable oil, or recycled greases have significantly different and widely varying properties that are not acceptable for use in modern diesel engines. For example, the higher viscosity and chemical composition of unprocessed oils and fats have been shown to cause problems in a number of areas: (i) piston ring sticking; (ii) injector and combustion chamber deposits; (iii) fuel system deposits; (iv) reduced power; (v) reduced fuel economy and (vi) increased exhaust emissions. Use of unprocessed oils or fats as neat fuels or blending stock will lead to excessive fuel condensation and corresponding dilution of the engine's lubricating oil that may result in sludge formation [E.M.A].

Any or all of these conditions may result in reduced engine life, increased maintenance costs, or catastrophic engine failure. Moreover, the problems associated with the use of raw vegetable oil or animal fat may not become evident until a significant amount of damage has occurred over an extended period [Jinlin Xue at al.].

The significantly higher viscosity of raw vegetable oils (27-54 mm²/s) compared to petroleum diesel fuel (2.6 mm²/s) alters fuel injector spray patterns and spray duration, adds stress on fuel injection systems, and results in incomplete combustion and high dilution of the engine lubricating oil. In turn, fuel injector spray pattern, duration, etc. affect the combustion process and the resulting engine performance and emissions levels. This incomplete combustion increases fuel dilution of engine lubricating oil and leads to sludge development. In addition, the polymerization of glycerides in raw vegetable oils and animal fats during the combustion process results in undesirable deposits on pistons, piston rings, fuel injectors,

valves, etc. It is important to note that such effects may not be immediate, but occur over a period of weeks or months depending on engine use and fuel system design [E.M.A].

4. Methodology

The methodology of synthesis a biodiesel from waste cooking oil is summarized in following steps and the materials are: waste cooking oil, catalyst represented by NaOH and the methanol as the main component of reaction. The waste vegetable oil used in this work is a mixture of corn oil, palm oil and sunflower oil collected from local food restaurants. Process of transesterification is presented as shown in figure 1. The experiment procedures are:

1. Filtering the waste cooking oil from the impurities.
2. Test different ratio of catalyst (3-7) gram, methanol (100 – 150) ml and heating temperature of waste cooking oil (57-64) and the optimum ratio is used to synthesize the biodiesel.
3. Mixing the optimum ratio or reactors as: (4gm) of sodium hydroxide NaOH and (130 ml) of methanol in a beaker and solving the NaOH in methanol totally.
4. Heating 1 liter of waste cooking oil up to 60 °C. Water bath is selected for this purpose because it's giving steady state heating rate and keeping the temperature of waste oil constant. The temperature of water was 62 °C.
5. Adding the mixture of (NaOH and methanol) to the heated waste oil at 60 °C and mixing them by use electric stirring for 1 hour.
6. Keeping the mixture at separate funnel for one day.
7. Wash the biodiesel and collect it.

5. Results and discussion

Different properties are tested in Advance scientific laboratories – college of materials/ university of Babylon-Iraq for the waste cooking oil and its synthesized biodiesel. Figures 1 and 2 give the biodiesel scheme and the glycerin. Table 1. shows the results of properties testing.

Depend on volumetric analysis, the amount of synthesized biodiesel is calculated. As mentioned above, 1 liter of waste cooking oil is used in the experimental investigation. The 94% by volume is biodiesel and rest is glycerin. The temperature of reaction and the weight of catalyst are the effective factor on the quantity of synthesized biodiesel.

Table 1. shows the comparison between the properties of density, viscosity, cetane number, flash point, pour point and net caloric value.

The transesterification process is enhanced the fuel properties in the biodiesel as a compare with its oil.

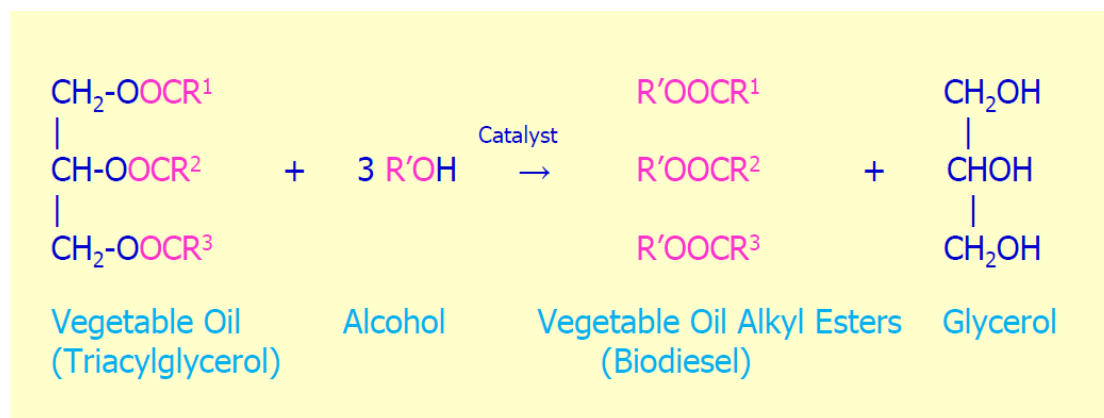


Figure 1. The transesterification process



Figure 2. Biodiesel and glycerin

Table 1. Properties of waste cooking oil, its biodiesel and diesel.

Property	Waste oil	Synthesis biodiesel	Diesel [S.Talwade 1, M. Navindgi]
Density (kg/m ³) at 15 oC	0.931	0.897	0.840
Viscosity (mm ² /sec) at 40oC	26.40	5.08	1.9 ~ 2.3
Cetane number	49	54	40~45
Flash point (K)	509	438	340
Pour point (K)	-15	-6	4.4
Net caloric value (MJ/kg)	33.15	35.67	43.5

6. Economic side of biodiesel synthesizes:

The calculation of the cost of one liter synthesize biodiesel price is pointed that 0.2 dollar/liter is the library cost of biodiesel. While the local price of diesel is 0.4 dollar/liter [fuel price data Iraq].

The economic calculation of biodiesel price is dependent on the prices of: waste cook oil, methanol, catalyst and operating cost in the laboratory. The bulk production is less cost than laboratory. In addition to this, the cost of get rid of waste cook oil is high and pollute the water or land.

7. Conclusion

In present work, the following points it might concluded:

- 1- At 60 °c and 4 gram of NaOH the synthesized biodiesel is 94% by volume of reacted quantity.
- 2- The biodiesel properties are comparative and promising to use the biodiesel as supplementary fuel to the diesel totally or partially.
- 3- The economic calculation shows that one liter of biodiesel synthesized in laboratory is
- 4- cheapest than one liter of local conventional diesel.
- 5- The transesterification of waste cook oil to biodiesel avoids the environment from pollution and offers clean and renewable fuel.

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