Combination of biodiesel, glycerol, and methanol as liquid fuel

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Abstract. Waste frying oil is a harmful liquid to human body and environment. However, it can be utilized as fuel. Transesterification of waste frying oil with methanol is presence of potassium hydroxide as catalyst produces fatty acid methyl ester (FAME) known as biodiesel as main product with glycerol as byproduct. Previously, several researches have been carried out concerning about utilization of both substances as renewable liquid fuel. In this research, three materials biodiesel, glycerol, and methanol which involved in transesterification process are combined in order to determine another renewable liquid fuel. Combination with composition 1:1:1 to 1:1:4 (v/v) is burned in an external combustion engine. Viscosity of glycerol is the main problem to form fuel for the engine. The result shows that the higher percentage of the methanol, the easier is the combustion. Composition by volume 1:1:4 of biodiesel, glycerol, and methanol respectively is the best mixture of liquid fuel for boiler burner.

1. Introduction
Environmental sustainability is a major issue recently. Determining a renewable source of energy is another to consider. Production of renewable and sustainable fuel from plants becomes more intensive since fossil fuel reserves continuously decreasing. In Indonesia, several researches have already carried out in order to determine renewable fuel especially biodiesel that produced from palm oil. On contrary, the palm oil is also used for domestic and industrial daily purpose such as for frying. It is well known that frying oil is one of nine basic needs for Indonensian people. Consequently, using palm oil as raw material for biodiesel production is not a great option. Avoiding conflict of interest on palm oil utilization, this research attempts to make biodiesel from waste frying oil (WFO).

During frying process, at least 30% WFO is left and it is harmful to human health as well as to environment [1]. Alternatively, WFO must be converted into renewable fuel called biodiesel. Previous experiment showed that transesterification method could reach almost 100% conversion [2,3]. During frying process, palm oil is usually exposed to an extreme heat to more than 190 °C. At this temperature and higher, most organic nutritious substances are decomposed. Chemically, frying also cause acid number tends to increase. This is another problem that must be taken care prior transesterification process. Furthermore, this process may cause formation of several harmful and carcinogenic substances, for example aldehydes, acroleines, and peroxydes [3]. Therefore, WFO must not be consumed. It is better to convert WFO into a liquid fuel by transesterification.

Transesterification of WFO and methanol using basic catalyst, such as potassium hydroxide (KOH), producing biodiesel as main product and glycerol as byproduct, with a chemical reaction as figure 1 follows.
Commonly, this biodiesel is called fatty acid methyl ester (FAME) and used as fuel to replace conventional diesel fuel that produced from fossils [3]. Unfortunately, glycerol produced at this point is slippery dark brown viscous liquid with strong odour. Therefore, this byproduct mostly discharged into environment through water system. Since glycerol is soluble in water (hydrophilic), it is potentially may cause water pollution [4]. Consequently, it is not in accordance with principle of environmentally friendly. Moreover, it is a ginst sustainabilty development goals as stated by the UN on October 21st, 2015 [5].

In order to increase environment quality and determine sustainable renewable fuel, production of biodiesel must not create another waste. A biofuel production with zero waste must be taken into account. In other words, glycerol as byproduct of transesterification must be processed to create more valuable material. During transesterification, there are three major liquids involved, namely biodiesel, glycerol, and methanol. Objectives of this research is to replace ordinary diesel fuel comes from fossil, which almost runs out and unrenewable, by combining and mixing these liquids to create a renewable fuel.

2. Methodology

Transesterification is carried out by mixing waste frying oil, that has been filtered to separate solid contents, with methanol containing a strong base potassium hydroxide (KOH) as catalyst in a three necked roundbottom flask. Pretreatment is required in order to keep waste frying oil clear and solid free [6,7]. The treatment is also intended to keep acid number of waste frying oil less than 3 [2]. The flask was also equipped with an electric stirrer operated at 70 rpm to ensure the mixture reacts thoroughly. The mixture then was heated using an electric water bath with temperature was automatically kept around 64 °C, just below the boiling point of methanol. This process was carried out for at least one hour for complete reaction. After that, the mixture was allowed to cool and reach room temperature. In order to speed up cooling process, the flask was immersed in a cool water bath. Next, the mixture was transferred into a conical flask for separation. In the flask, two layers were formed naturally due to difference in density. Top layer was biodiesel and the bottom layer was glycerol [2]. The layers were separated by opening the valve near the bottom of the flask as shown on following Figure 2.
Volume of each liquid layer, biodiesel and glycerol, was measured by means of a measuring cylinder. Physical properties of both liquid were separately analysed and calculated. They were viscosity, combustion energy, density, flash point, and molar mass [8]. Density was analyzed using a digital densitometer while viscosity was analyzed using viscometer refer to ASTM. Boiling point was analyzed using a distillation methods. Finally, the colour was analysed by means of a UV-Vis spectrophotometer.

Afterwards, a series of composition were prepared by mixing three liquids, namely biodiesel, glycerol, and methanol in four flasks. The compositions were 1:1:1, 1:1:2, 1:1:3, and 1:1:4 based on volume. Densities of these compositions were measured. Each composition then applied to a boiler burner replacing ordinary diesel fuel. Pressurized air was also added to the composition and controlled to create optimum flame. Appearance of the flame was closely monitored and compared to common flame that usually produced when burning ordinary diesel fuel. This procedure was repeated to all of the compositions.

3. Results and discussion
According to measurement at laboratory and calculation based on technical data, values of their physical properties are shown on Table 1.

| Substance | Viscosity (Pa.s) | Energy (kJ/mol) | Density (kg/liter) | Auto Ignition (°C) | Molar Mass (gram/mol) |
|-----------|-----------------|-----------------|--------------------|-------------------|-----------------------|
| Biodiesel | 36-50           | 37,270          | 0.880              | >130              | varies                |
| Glycerol  | 1,412           | 1,654           | 1.261              | 393               | 92                    |
| Methanol  | 0.545           | 715             | 0.792              | 470               | 32                    |

According to the experiment, every liter mixture of waste frying oil and methanol produces around 700 ml of biodiesel and 300 milliliter of glycerol [2]. Appearance of biodiesel is a clear yellow liquid while glycerol at this point is slippery and viscous with dark brown colour. In mixtures of those three liquids with compositions 1:1:1 to 1:1:4, the viscosity and density gradually decrease as proportion of methanol increase as shown on Figure 3 and Figure 4.

![Figure 3. Viscosity of the composition decreasing as methanol percentage increase.](image-url)
Figure 4. Density of the composition decreasing as methanol percentage increase.

Eventhough waste frying oil was filtered using filter paper and vaccum system to remove solid contents, the colour of biodiesel produced was still dark brown. Impurities in form of tiny particles cannot be removed. Physically, almost all impurities was formed at the bottom layer or glycerol layer. It means that biodiesel produced at the top layer was clear and colourless. After separation, glycerol was filtered one more time [9].

During application of these compositions on boiler burner, viscosity is the major obstacle on this experiment. Normally, using ordinary diesel fuel, the fuel pump works with medium pressure, the colour of flame is blueish red, and the amount of soot is small. However, viscosity of glycerol is very high compared to the other liquids, biodiesel and methanol. Since methanol has the lowest viscosity, proportion of this liquid is the key to have a liquid fuel with reasonable viscosity. Viscous liquid causing fuel pump works harder than usual. Furthermore, the viscous liquid, especially at composition 1:1:1, cannot form droplets easily even the pressure of the fuel pump is high. Consequently, quality of flame created using viscous liquid is unacceptable since the colour of the flame is blackish red with a large amount of soot.

Table 2. Description of composition, fuel pump pressure, colour of flame, and amount of soot.

| Composition (v/v) | Fuel Pump Pressure | Colour of Flame | Amount of Soot |
|------------------|--------------------|-----------------|---------------|
| 1:1:1            | Very High          | Blackish Red    | Large         |
| 1:1:2            | Very High          | Blackish Red    | Large         |
| 1:1:3            | Very High          | Blackish Red    | Large         |
| 1:1:4            | High               | Blackish Red    | Medium        |

4. Conclusion
Glycerol can be used as additional liquid to create a renewable fuel. The best liquid fuel for boiler burner is a mixture of biodiesel, glycerol, and methanol at proportion of 1:1:4 (v/v) respectively.

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