

Biodiesel production from waste cooking oil collected from hotels and restaurants

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Abstract: Biodiesel is an alternative fuel, which is similar to conventional fuel or fossilized fuel. Biodiesel can be produced from straight vegetable oil, animal fats/oil, tallow and waste cooking oil. In this study, waste cooking oil (WCO) was used to produce biodiesel, which were collected from several hotels and restaurants of Tangail municipality area. This study was accomplished by trans-esterification process where methanol (CH₃OH), potassium hydroxide (KOH) and WCO were used as raw materials to produce biodiesel. In this study, we got 347 ml of biodiesel from 400 ml of WCO having conversion rate 86.7%. Moreover, physical properties of produced biodiesel including density, viscosity, flash point, water content were measured in this study, which were like the American standard of testing material (ASTM) value of biodiesel.

Keywords: Biodiesel, waste cooking oil (WCO), alternative oil, physical properties of biodiesel.

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1. INTRODUCTION

Now a days gaseous air pollutants are creating several global and local environmental issues including climate change, global warming, acid deposition in soil and aquatic environment, which finally affects human lives and properties (Hoque *et al.*, 2024; Hoque *et al.*, 2020; Mukta *et al.*, 2020). Atmospheric particulates (PM_{2.5}) concentration (80 µg/m³) in the urban areas of Bangladesh is ~5 times higher than the Bangladeshi standard and 8 times higher than those of WHO guidelines (World Bank, 2018). Consequently, inferior quality of air throughout the country is prompting damage to public health, agricultural productivity and assets (Hoque *et al.*, 2024, Hoque *et al.*, 2022b; Mukta *et al.*, 2020). For an example, the economic cost of mortality due to air pollution in Dhaka city is estimated at US\$310 million, which is equivalent to 0.1 percent of Bangladesh's GDP in 2015 (World Bank, 2018). So, it is high time to find out alternatives to traditional (fossil) fuels for combating air pollution and facing global environmental challenges. Moreover, discarded waste cooking oil towards soil and water results in soil and surface water contamination.

In fact, scarcity of conventional fossil fuels, growing emissions of combustion generated pollutants, and their increasing costs will make biomass sources more attractive to user (Sensoz *et al.*, 2000). On the other hand, biomass use, in which many people already have an interest, has the properties of being a biomass source and a carbon-neutral source (Dowaki *et al.*, 2007). Experts suggest that current oil and gas reserves would suffice to last only a few more decades. To meet the rising energy demand and replace reducing petroleum reserves, fuels such as biodiesel and bioethanol are in

the forefront of alternative technologies. Accordingly, the viable alternative for compression-ignition engines is biodiesel (Demirbas, 2002).

Biodiesel is briefly defined as the mono-alkyl esters of vegetable oils or animal fats; this is the best contestant for diesel fuels in diesel engines. Biodiesel burns like petroleum diesel as it involves regulated pollutants. On the other hand, biodiesel probably has better efficiency than gasoline. Biodiesel also exhibits great potential for compression-ignition engines. Diesel fuel can also be replaced by biodiesel made from vegetable oils. Biodiesel is now mainly being produced from soybean, rapeseed, and palm oils. The higher heating values (HHVs) of biodiesels (39 to 41 MJ/kg) are slightly lower than those of gasoline (46 MJ/kg), petrodiesel (43 MJ/kg), or petroleum (42 MJ/kg), but higher than coal (32 to 37 MJ/kg) (Demirbas, 2002).

However, if biodiesel is pure or 100% biodiesel fuel, it is referred to as B100 or "neat" fuel. A biodiesel blend is pure biodiesel blended with petro-diesel. Biodiesel blends are referred to as BXX. The XX indicates the amount of biodiesel in the blend (*i.e.*, a B80 blend is 80% biodiesel and 20% petro-diesel). Currently, world's energy demand is fulfilled by conventional energy sources like coal, petroleum, and natural gas. Petroleum-based fuels are limited reserves concentrated in certain regions of the world. These sources are on the verge of reaching their peak production. The scarcity of known petroleum reserves will make renewable energy sources more attractive (Sheehan *et al.*, 1998).

World energy demand continues to rise. The most feasible way to meet this growing demand is by using alternative fuels. One such fuel that exhibits great potential is biofuel, in

particular biodiesel (Fernando *et al.*, 2006). The term biofuel can refer to liquid or gaseous fuels for the transport sector that are predominantly produced from biomass (Demirbas, 2006). Bio-fuels include energy security reasons, environmental concerns, foreign exchange savings, and socioeconomic issues related to the rural sector (Reijnders, 2006). In developed countries there is a growing trend toward using modern technologies and efficient bio-energy conversion using a range of bio-fuels, which are becoming cost wise competitive with fossil fuels (Puhan *et al.*, 2005).

It is well known that transport is almost totally dependent on fossil, particularly petroleum, based fuels such as gasoline, diesel fuel, liquefied petroleum gas (LPG), and natural gas (NG). An alternative fuel to petro-diesel must be technically feasible, economically competitive, environmentally acceptable, and easily available. The current alternative diesel fuel can be termed biodiesel. Biodiesel use may improve emissions levels of some pollutants and deteriorate others. However, for quantifying the effect of biodiesel it is important to consider several other factors such as raw material, driving cycle, vehicle technology etc. Use of biodiesel will allow a balance to be sought between agriculture, economic development, and the environment (Meher *et al.*, 2006).

2. Objectives

This study was performed to satisfy the following objectives:

- i) To develop a convenient process to produce biodiesel from waste cooking oil.
- ii) To examine the physical and chemical properties of produced biodiesel and compare it with international standards.

3. Methodology of the study

3.1. Sampling

Presently, 320 hotels and restaurants are operating in the Tangail municipality area, which are frequently using soya bean oil for making and frying different local foods called puri, shingara, somocha, piyaju and luchi etc. Ten (10) waste cooking oil (WCO) samples were collected from the selected hotels and restaurants, which were selected on the basis of selling volume. For each sample, about 1 L of WCO was collected in a pet bottle. The collected samples were stored in normal temperature until analysis.

3.2. Raw materials for biodiesel

i) Waste cooking oil

Waste cooking oil (WCO) is generated from the fried food, which need large amounts of oil because it requires the full immersion of food at temperatures greater than 180°C. Accordingly to the high temperatures are generated during cooking of fried food, changes in its chemical and physical composition, as well as in its organoleptic properties. Hence, affect both the food and oil quality. Used cooking oil is normally black, a strong odor and does not have large number of solids because its collection is passed through a fine mesh (Guerrero-Romero *et al.*, 2011).

ii) Alcohol

Primary and secondary alcohols with string of 1-8 carbons are used for the biodiesel production, among the alcohols that can be used in

this process are: methanol, ethanol, propanol, butanol (Cujia and Bula, 2010). If methanol is used it would not contribute to environmental issues and sustainability, biodiesel would not be completely bio, by having a fossil component provided by the alcohol, because methanol is made from natural gas, which is fossil (Cheng *et al.*, 2008). During the reaction form emulsions, using methanol is easy and quickly dissolved, forming a glycerol-rich bottom layer and a higher layer in methyl esters (Arbeláez and Rivera, 2007). It is preferred to use methanol in the biodiesel production because of their low viscosity, because using alcohols such as ethanol with high viscosity, the biodiesel viscosity increases and as a result a "fuel of high viscosity will not be pulverized properly by injection systems that have diesel engines. With the above, the methanol is selected to be used in the biodiesel production due to its lower cost, better performance and less time and energy during the reaction.

iii) Catalysts

The catalysts can be acids or alkalis, the acid catalysts are effective but require a time interval extremely long and temperatures exceeding 100 °C for its action (EREN, 2003). We can use sulfuric acid (H₂SO₄), phosphoric acid (H₃PO₄), among others. When are used acid catalysts with alcohol excess is that the recovery of glycerin is more difficult as the quantities of alcohol are quite large compared to other type of catalyst (Arbeláez & Rivera, 2007). The basic catalysts accelerate the reaction rate. The disadvantage of basic catalysts is that produces soaps due to the high amounts of free fatty acids and water by which we must add the appropriate amount of base to neutralize fatty acids free. The most used are sodium hydroxide (NaOH), potassium hydroxide (KOH) and inappropriate for industrial application (CH₃ ONa) sodium methoxide since this is more expensive and requires total absence of water (EREN, 2003).

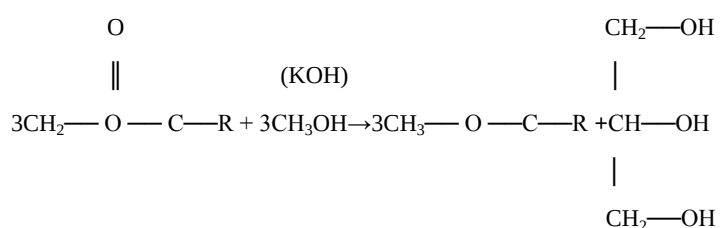
3.3 Analytical procedure

3.3.1 Sample preparation

The collected waste cooking oil was filtered by piece of cotton cutting cloths to remove dirt and of food residues from the sample. Filtered cooking oil will then be collected in a clean conical flask and will be used for experiments. An appropriate volume (200 ml) of alcohol was measured and poured into a 500 ml conical flask. The catalyst in pellet form was weighed and mixed with alcohol. The mixture was then shaken for about 1 hour. Since alcohols evaporate easily, the flask should be covered with aluminum foil during shaking to prevent the evaporation of alcohol, which will prevent the alkoxide from absorbing water from the air.

3.3.2 Trans-esterification

Trans-esterification is the most common process, in this process an ester compound is exchanged by an alcohol in the alkyl group (Javidialesaadi and Raeissi, 2013). In trans-esterification reaction, the triglyceride component of used cooking oil reacts with alcohol in the presence of KOH or any other catalyst to give ester and glycerol as shown in the reaction scheme-1 (Ali *et al.*, 2017).



Triglyceride Methanol Esters Glycerol

Where, R is long chain hydrocarbons.

Scheme-1: A schematic representation of the trans-esterification reaction (Ali *et al.*,2017).

3.3.3 Procedure of biodiesel production

Step-1: Collect 1.0 L cooking oil as samples in a pet bottle from different hotels and restaurants of Tangail Pauroshova

Step-2: Filtration of the waste cooking oil by using cotton clothes and is stored into bikers using funnel.

Step-3: Take 400 ml of filtered sample oil into another biker.

Step-4: Take 100 ml methyl alcohol in the biker.

Step-5: Take 10 gm potassium hydroxide (KOH) in a conical flask.

Step-6: Then put methyl alcohol (CH₃OH) in the conical flask and stir this solution by a stirring rod for better mixing.

Step-7: Take 500 ml of sample cooking oil glass bottle, pour mixture of potassium hydroxide (KOH) and methyl alcohol (CH₃OH) into the glass bottle and shake it for 10 minutes and wait for few minutes until the solution get settled.

Step-8: Then put this glass bottle into the electric oven at temperature of 120 °C for 2 hours.

Step-9: After 2 hours heating, take the hot bottle from the oven and wait until it's normal temperature.

Step-10: Then we noticed the appearance of two layers: i) upper layer is biodiesel and ii) lower layer is glycerol. We separate biodiesel from the bottle into bikers using pipette and collect glycerol into another biker.

3.3.4 Physical properties of biodiesel

Five physical properties of biodiesel including density, viscosity, water content, flash point and ash content were measured in this study. Density and viscosity were measured in the chemistry lab, Department of Chemistry, Mawlana Bhashani Science and Technology University. The water content, flash point and ash content are measured in the Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka.

3.3.4.1 Procedure of measuring density of biodiesel

Following are the steps are adopted to measuring the density of biodiesel

Step-1: First, we take 50 ml empty bottle then measured it's weight.

Step-2: We filled the empty bottle with water and weighed it again.

Step-3: Again, we filled the empty bottle with biodiesel and weighed it.

We measured density of biodiesel by the following equation,

$$\text{Density} = (y_2 - x_1) / (y_1 - x_1)$$

Where,

x_1 = the weight of empty bottle.

y_1 = the weight of bottle with water.

y_2 = the weight of bottle with biodiesel.

3.3.4.2 Procedure of measuring viscosity of biodiesel

Viscosity is measured by Gravimetric viscosity meter. We follow the following steps for measuring viscosity:

Step-1: First, fill the gravimeter with water and calculate the finishing time.

Step-2: Then we fill the gravimeter with biodiesel and calculate the finishing time.

Step-3: We can do it for several time and record the time.

Viscosity of the biodiesel was measured by following equation,

$$n_2 = \{[(p_2 \times t_2) / (p_1 \times t_1)] \times n_1\}$$

Where,

n_2 = viscosity of sample biodiesel

n_1 = viscosity of water

p_2 = density of sample

p_1 = density of water

t_2 = finishing time of sample

t_1 = finishing time of water

4. Results and discussion

4.1 Biodiesel production from WCO sample

As shown in Table 1, minimum biodiesel produced from 400 ml of WCO sample (sample WCO1-WCO10) was 340 ml, and maximum 355 ml, average 347 ml. Highest amount 355 ml biodiesel produced from sample WCO1, where conversion rate was of WCO to biodiesel was 88.7%. However, we got the lowest amount of biodiesel from sample WCO2 and WCO4, having conversion rate 85% of WCO to biodiesel.

Table 1. Production of biodiesel from the collected samples

Sample (400 ml) no.	Biodiesel (ml)	Percentage of biodiesel (%)
WCO1	355	88.7
WCO2	340	85.0
WCO3	345	86.0
WCO4	340	85.0
WCO5	350	87.5
WCO6	346	86.5
WCO7	346	86.5
WCO8	348	87.0
WCO9	354	88.5
WCO10	347	86.8
Min	340	85.0
Maximum	355	88.7
Average	347	86.7

4.2 Physical properties of produced biodiesel

4.2.1 Density

Fuel density is a key property that affects engine performance. Since, fuel injector pumps the fuel by volume, not by mass, a greater or lesser mass of fuel is injected depending upon its density. Thus, the air fuel ratio and energy content within the combustion chamber are influenced by fuel density, which affects the combustion in a diesel engine physically. Furthermore, a lower density fuel requires longer injection duration for the same fuel mass to be injected. In general, densities of biodiesel fuels are slightly higher than those of mineral diesel (~6%) (Ali *et al.*, 2017). As shown in Table 2, density of produced biodiesel was 0.86 gm/cc, which was very close to the standard density of biodiesel 0.87 gm/cc mentioned by American Standard of Testing Material (ASTM).

5.2.2 Viscosity

Viscosity is a measure of resistance to the flow of a liquid due to the internal friction of one part of a fluid moving over another and is based on the molecular structure and temperature. This is a critical property because it affects the behavior of fuel injection, since an accurate amount of fuel is needed for injection. In general, higher viscosity leads to poorer fuel atomization. High viscosity can cause larger droplet sizes, poorer vaporization and narrower injection spray angle. High viscosity can lead to overall poorer combustion, higher emissions, and increased oil dilution. The viscosity of biodiesel is typically higher than that of mineral diesel often by a factor of two. If the fuel viscosity is high, the injection pump will be unable to supply sufficient fuel to fill the pumping chamber, which will affect in the form of power loss from the engine. On the other hand, if the viscosity is too low, leaking can occur through the seals in the fuel injection system. Furthermore, many of the problems resulting from high viscosity are most noticeable under low ambient temperature and cold-start engine conditions (Ali *et al.*, 2017). According to American Standard of

Testing Material (ASTM) the standard value of biodiesel's viscosity is 1.9-6.5 mm²/s. Our measured viscosity is 6.178 mm²/s which is within the standard value range (Table 2).

5.2.3 Water Content

Water has either of two forms: dissolved water or suspended water droplets. While biodiesel is generally considered to be insoluble in water, it actually takes up a considerably greater amount of water than does diesel fuel. On the other hand, the water content of biodiesel reduces the heat of combustion and causes corrosion of vital fuel system components. The standards of water content are ASTM, which limit the amount of water to be maximum of 0.05 (v %) (Chandrasekaran *et al.*, 2019). According to American Standard of Testing Material (ASTM) the standard value of biodiesel's water content is maximum 0.05%. However, the measured value of water content is nil in the present study (Table 2).

5.2.4 Flash point

Flash point of a fuel is the temperature at which it will ignite when exposed to a flame or spark. The flash point of biodiesel is higher than the petro-diesel, which is safe for transportation purposes (Meher *et al.*, 2006). Flash point is inversely related to fuel volatility. The biofuel specifications for flash point are meant to guard against contamination by principally highly volatile impurities and excess methanol remaining after the product stripping processes. Even small amounts of residual methanol in biodiesel will cause a significantly depressed flash point. The flash point value for all biodiesel types is typically well above the flash point of diesel fuel by 25-90%. Compared to mineral diesel, palm oil biodiesel has a higher flash point by about 78% (Ali *et al.*, 2017). As shown in Table 2 flash point of the biodiesel of the current study was higher than biodiesel produced from palm oil (Ali *et al.*, 2017). However, this value is very close to 130-170°C ASTM, the standard value of biodiesel's flash point.

5.2.5 Ash content

Ash content describes the quantity of inorganic contaminants such as abrasive solids and catalyst residues, and the concentration of soluble metal soaps contained in a fuel sample.

Ash content represents the incombustible component remaining after a sample of the furnace oil is completely burned. The ash content of petroleum products is generally low. It is defined

as inorganic residue that remains after combustion of the oil in air at specific high temperature. As shown in Table 2, ash content in the present study ranges from 0%-0.1%. Some of the ash forming constituents occur naturally in crude oil; others are present because of refining or contamination during storage or distribution. According to American Standard of Testing Material (ASTM) the standard value of biodiesel's ash content is 0.01%. However, the measured ash content for the produced biodiesel was nil (Table 2).

Table 2. Physical properties of produced biodiesel

Physical properties	Measured value	ASTM standard
Density (gm/cc)	0.86	0.87
Viscosity (mm ² /s)	6.2	1.9-6.5
Water content, %(v/v)	Nil	0.05% (max)
Flash point, °C	157	120-170
Ash content, %(w/w)	Nil	0.01%

Conclusion

Waste cooking oil is harmful to human health when reused and is also toxic to the environment if it is disposed to the environment (water and soil). So, the best solution is to use it for another purpose such as use in industry, transportation sector, and domestic uses as converted biodiesel. In this study methanol (CH₃OH) and potassium hydroxide (KOH) react with waste cooking oil, which produces biodiesel and glycerol as by product. Glycerol can be used as fertilizer when it reacts with methanol. However, the focus of this research was to produce biodiesel from waste cooking oil (WCO). In this research 400 ml WCO react with 100 ml methanol and 10 gm KOH and produced 350 ml (avg. 347 ml) biodiesel and 150 ml glycerol. The quality of produced biodiesel was very good and satisfactory, since it meets most of the physical standard criteria of biofuel mentioned by ASTM. So, this study may be used as suitable insight for conversion of waste to energy.

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