

Biodiesel from Coconut Oil: A Renewable Alternative Fuel for Diesel Engine

Md A. Hossain, Shabab M. Chowdhury, Yamin Rekhu, Khandakar S. Faraz, Monzur Ul Islam

Abstract—With the growth of modern civilization and industrialization in worldwide, the demand for energy is increasing day by day. Majority of the world's energy needs are met through fossil fuels and natural gas. As a result the amount of fossil fuels is on diminishing from year to year. Since the fossil fuel is non-renewable, so fuel price is gouging as a consequence of spiraling demand and diminishing supply. At present the power generation of our country is mainly depends on imported fossil fuels. To reduce the dependency on imported fuel, the use of renewable sources has become more popular. In Bangladesh coconut is widely growing tree. Especially in the southern part of the country a large area will be found where coconut tree is considered as natural asset. So, our endeavor was to use the coconut oil as a renewable and alternative fuel. This article shows the prospect of coconut oil as a renewable and alternative fuel of diesel fuel. Since diesel engine has a versatile uses including small electricity generation, an experimental set up is then made to study the performance of a small diesel engine using different blends of bio diesel converted from coconut oil. It is found that bio diesel has slightly different properties than diesel. With biodiesel the engine is capable of running without difficulty. Different blends of bio diesel (i.e. B80, B60, and B 50 etc.) have been used to avoid complicated modification of the engine or the fuel supply system. Finally, a comparison of engine performance for different blends of biodiesel has been carried out to determine the optimum blend for different operating conditions.

Keywords—Biodiesel, Bio-fuel, Renewable Energy, Transesterification

I. INTRODUCTION

FUEL and energy crisis and the concern of the society for the depleting world's non-renewable energy resources led to a renewed interest in the quest for alternative fuels. One of the most promising alternatives fuel is the vegetable oils and their derivatives. The first use of vegetable oil in a compression ignition engine was first demonstrated through Rudolph Diesel who used peanut oil in his diesel engine [1]. The use of oils from coconut, soybean, sunflower, safflower, peanut, linseed, rapeseed and palm oil amongst others have been attempted. The long term use of vegetable oils led to injector coking and the thickening of crankcase oil which resulted in piston ring sticking.

Therefore, vegetable oils are not used in SI engines because of endurance issues [2].

To overcome this problem, various modifications of vegetable oils have been employed such as transesterification, micro-emulsion formation and the use of viscosity reducers [3]. Among these, transesterification was considered as the most suitable modification because technical properties of esters are nearly similar to diesel. Through transesterification, these vegetable oils are converted to the alkyl esters of the fatty acids present in the vegetable oil [4, 5]. These esters are commonly referred to as biodiesel. Biodiesel is an alternative fuel that is renewable in the sense that its primary feedstock has a sustainable source. Some other feed stocks that can be converted to biodiesel are waste restaurant grease and animal fat [6, 7]. These sources are less expensive than vegetable oil.

In view of the current instability in oil prices, biodiesel stands as an attractive source of alternative energy. By adopting and increasing the use of biodiesel, European countries have reduced from her over-dependence on crude oil reserves [8]. Besides, conventional fossil fuel has been reported as being finite. While it is worthy to note that biodiesel will not completely displace petroleum diesel, biodiesel has its place as an alternative fuel and can be a source of lubricity as an additive to diesel fuel. The emissions produced from biodiesel are cleaner compared to petroleum-based diesel fuel. Particulate emissions, soot, and carbon monoxide are lower since biodiesel is an oxygenated fuel. However, emissions of oxides of nitrogen (NO_x) are higher when biodiesel is used [9]. The cause of the rise in NO_x is unknown and is being studied.

One particular problem of biodiesel is its cold flow properties. Neat biodiesel such as methyl soy ate has a pour point (i.e. the lowest temperature at which the fuel is pourable) of -3°C [1]. In colder climates, crystallization can occur, which leads to the plugging of fuel filters and lines. Typically, taking U.S as a case study, biodiesel is blended with diesel fuel. A B20 blend would be 20% biodiesel in diesel fuel [10]. Such a blend would have better cold flow properties compared to neat biodiesel. This work is therefore aimed at producing biodiesel from ethyl esters of coconut oil and comparing some properties of the produced biodiesel with ASTM standards.

II. PRODUCTION PROCESS

A. Biodiesel

Biodiesel is produced from vegetable oils. The main components of vegetable oil are triglycerides. Triglycerides are esters of glycerol with long chain fatty acids, commonly called fatty acids. Bio-diesel is defined as mono alkyl esters of long chain fatty acids from renewable feed stock such as vegetable oil or, animal fats, for use in compression ignition (IC) engines [11]. This name is given to esters when they are used as fuel.

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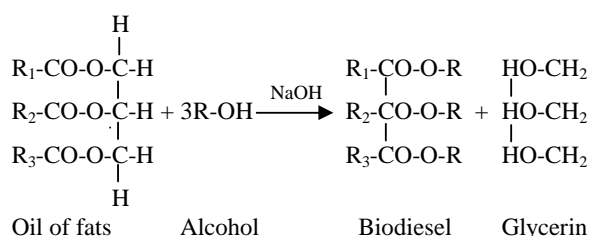
B. Blends

Blends of biodiesel and conventional hydrocarbon-based diesel are products most commonly distributed for use in the retail diesel fuel marketplace. [12] Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix:

- 100% biodiesel is referred to as B100, while
- 20% biodiesel, 80% petro diesel is labeled B20
- 5% biodiesel, 95% petro diesel is labeled B5
- 2% biodiesel, 98% petro diesel is labeled B2

C. Transesterification Process

Coconut oil like any other vegetable oils and animal fats are triglycerides, inherently containing glycerin. The biodiesel process (transesterification) turns the oils into esters, separating out the glycerin from the main product (biodiesel). The glycerin sinks to the bottom and the biodiesel floats on top and can be decanted off. The process is called transesterification, which substitute's alcohol for the glycerin in a chemical reaction, using a catalyst.



D. Materials used in Biodiesel Production

In the Laboratory scale production of biodiesel from coconut oil, the following materials were used; 1 liter of coconut oil, 200 ml of methanol 99+% pure, sodium hydroxide (NaOH) scales accurate to 0.1 grams.

The major feedstock source used in this work is coconut oil, locally produced in Bangladesh. By the stoichiometric equation of the process, 1 mol of coconut oil is required to react with 3 moles of methanol to produce 3 moles of the biodiesel and 1 mole of glycerol [15]. 100g coconut oil was used for the transesterification process.

A reaction temperature of 65°C was selected as reaction temperature for the process must be below the boiling point of alcohol (methanol, 78°C) used [14]. Different researchers have reported different reaction times for transesterification process as well as the entire biodiesel production process. The reported reaction time ranges from less than 15 minutes to more than 60 minutes [15]. Reaction time of 30 minutes was therefore selected.

Most researchers have used 0.1 to 1.2 % (by weight of oil) of catalyst for biodiesel production [15, 16]. 0.8% NaOH (by weight of coconut oil) concentration was therefore selected while 20% methanol was used.

E. Synthesis of Biodiesel from Coconut Oil

For the transesterification of coconut oil, the following steps were being followed in this work First 200 ml methanol was mixed with 150 ml (1 N) NaOH. As this is an exothermic reaction, so the mixture would get hot. This solution is known as sodium methoxide, which is a powerful corrosive base and harmful for human skin. So, safety precautions should be taken to avoid skin contamination during methoxide producing.

Next, sodium methoxide was added with 1 liter of coconut oil, which was preheated about 65°C. Then the mixture was shaken for 5 minutes in a glass container. After that the mixture was left for 24 hours (the longer is better). For the separation of glycerol and ester this mixture then gradually settles down in two distinctive layers. The uppermost transparent layer is 100% biodiesel and the lower concentrated layer is glycerol. The heavier layer is then removed either by gravity separation or with a centrifuge. In some cases if the coconut oil contains impurities, then a thin white layer is formed in between the two layers. This thin layer composes soap and other impurities. Then the biodiesel has been washed with distilled water in order to remove waste and a dry wash has been done by air-stone.

Biodiesel produced in the above process contains moisture (vaporization temperature 100°C), methanol (vaporization temperature 60°C) and usually some soap. If the soap level is low enough (300-500 ppm), the methanol can be removed by vaporization and the methanol will usually be dry enough to directly recycle back to the reaction. Methanol tend to act as a co-solvent for soap in biodiesel, so at higher soap levels the soap will precipitate as a viscous sludge when the methanol is removed. Anyway, heating the biodiesel at temperature above 100 °C would cause the removal of both the moisture and methanol as well.

F. Washing Method

Washing was done in two steps. In the first step, the collected biodiesel after transesterification reaction was taken into a beaker. Hot water (40°C) was poured into the biodiesel slowly. Then the mixtures were shaken slowly and the solution was kept 4 hours in stable position. Then a layer of soap has formed in the bottom of beaker. Then the biodiesel was collected by a pipe followed by siphoning method. the process had been repeated 4 times and gradually soap formation was reduced. The pH of the solution was also measured after each wash .This process is known as wet wash process.

TABLE I
COMPARISON OF PH AND SOAP FORMED 1 LITER BIODIESEL (B-100)

Test Run	Watered Used (ml)	pH	Soap Formed
1 st	200	9.67	High
2 nd	200	9.37	High
3 rd	200	8.84	Medium
4 th	200	8.75	Low

In other step, an air stone was used for producing bubbles in the solution for dry wash. Dry wash confirmed the formation of glycerol and soap rest in the mixture.

A heater was used which had been kept always 35°C for removing the water from biodiesel. After the process finally the biodiesel was collect and its properties were tested in the laboratory.

III. PROPERTIES OF BIODIESEL AND THEIR BLENDS ANALYSIS

Biodiesel produced from coconut oil has comparable fuel properties with the conventional fossil diesel. A comparative study of fuel properties with the conventional fossil diesel, neat biodiesel and their blends have been carried out in this work to find out suitable blending of biodiesel. In the study B40, B60, B80 and B100 blend have been prepared to compare the fuel properties of different blends.

A. Heating Value

Heating value indicates the energy density of the fuel. In our study, ASTM 2382 method has been applied to measure the heating value of biodiesel and their blends. Table 2 shows the heating value of diesel, neat biodiesel and their blends in MJ/kg.

TABLE II
COMPARISON OF HEATING VALUE OF DIFFERENT FUELS

Fuel	Heating Value (MJ/kg)
Fossil diesel	45.71
Neat Biodiesel B100	40.37
B80	41.44
B60	42.97
B40	44.13

From Table II it is observed that, diesel fuel has heating value about 45 MJ/kg. Heating value of the fuel decreases as we choose higher blending of biodiesel. This is because, biodiesel has lower energy density than diesel fuel, so higher amount of biodiesel is required for producing same amount of energy as compared to diesel fuel.

B. Viscosity

Viscosity of the fuel exerts a strong influence on shape of the fuel spray; high viscosity for example, causes low atomization (large droplet size) and high penetration of spray jet. Note that cold engines, with higher viscous oil, discharge will act almost a solid stream of fuel into the combustion chamber and starting may be difficult while a smoky exhaust will invariably appear. On the other hand, very low viscous fuel would cause to pass through leakage of the piston and piston wall especially after wear has occurred, which subsequently prevents accurate metering of the fuel. Fig. 1 indicates that, B40, B60 and B80 have almost the same viscosity at room temperature and it is about 1.5-2% higher than fossil fuel. But a slight preheating would cause to achieve comparable viscosity as that of diesel fuel. So using B40, B60, B40 and B80 blend would not cause much change on the fuel spray pattern, and thus these fuels can be used in the diesel engine without modification of the fuel supply system.

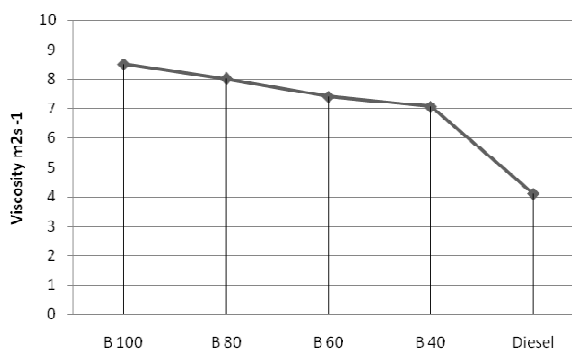


Fig. 1 Viscosity for diesel and biodiesel blends

On the other hand B100 is a much viscous fuel, and its viscosity is much higher than diesel fuel. The high viscous fuel would exhibit almost a solid stream of spray pattern in the combustion chamber and so cold starting of the engine would be difficult. So, using B100 fuel in the existing diesel engine would require modification of that fuel system so that fuel supply system exerts high sprat pressure to achieve the desired spray pattern inside the engine cylinder.

C. Flash Point

Flash point is an important property of CI engine fuel. Fig. 2 shows flash point for diesel, biodiesel and their blends.

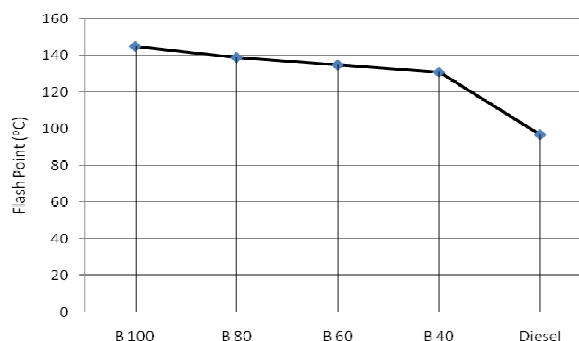


Fig. 2 Flash point for diesel and biodiesel blends

From Fig. 2 it is observed that flash point of B40 have about 1.25% higher than fossil diesel, and it attains same flash point as that of diesel fuel at 55° C. So preheating at this temperature is necessary for using it in CI engine. Similarly flash point of B60 has 1.35% higher than that of diesel fuel. And at temperature 60° C, it attains the same flash point as that of diesel fuel. For flash point of B100, it has about 1.5% higher than diesel fuel, and it requires preheating at 65° C to attain similar flash point as that of diesel fuel.

The flash point of the bio fuel is higher with higher blending of biodiesel. This is because, biodiesel has lower energy density than diesel fuel, so higher amount of compression ratio is required for producing same amount of energy as compared to diesel fuel.

IV. ENGINE PERFORMANCE TESTING AND ANALYSIS

A. Engine Parameter

The final product of biodiesel from coconut oil was used as an alternative fuel to operate a diesel engine and the performance data were recorded. The specification of the engine is given in table.

TABLE III
ENGINE SPECIFICATION

Model	ZS1110
Method of starting	Hand starting
Type	Horizontal, 4- stroke, 1 cylinder
Cylinder dia	70mm
Piston stroke	75mm
Nominal speed	2600 rpm
Nominal power	3HP
Cooling system	Air cooled
Rotation	Anti clockwise
Fuel filter	Present
Lube oil filter	Present

B. Experimental Setup

The experimental setup consisted of engine test bed with fuel supply system and different measuring and metering devices with the engine. A preheating system was made in diesel engine test bed with the help of heater and thermo couple for measuring the temperature. A control unit was used to set temperature and automatic control of heater. Separate tank had been used for direct use of coconut oil with mixing with diesel. Single tank has been used for testing biodiesel performance and a typical heater was used to preheat the oil both bio diesel and the direct using of oil. Brake horse power (bhp), Brake specific fuel consumption (bsfc), brake thermal efficiency, exhaust gas temperature of the engine was measured for Diesel, B100, B80, B60 and B40 blends. For measuring bhp, brake type dynamometer had been used. Test was run by varying fuel flow rate which was measured in kg/s.

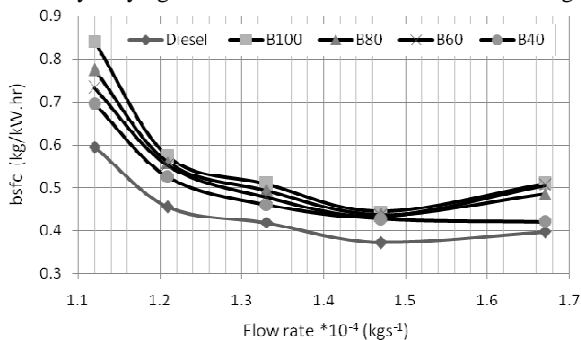


Fig. 3 Variation of bsfc with fuel flow rate

Fig. 3 shows the variation of bsfc with flow rate for different fuels. bsfc for biodiesel blends is higher at lower fuel flow rate. bsfc decreases with the increase of fuel flow rate. It is also observed that the bsfc increases with higher blends. This is mainly due to the relationship among volumetric fuel injection system, fuel specific gravity, viscosity and heating value.

As a result, more biodiesel blend is needed to produce the same amount of energy due to its higher density and lower

heating value in comparison to conventional diesel fuel. Again as biodiesel blends have different viscosity than diesel fuel, so biodiesel cause poor atomization and mixture formation and thus increases the fuel consumption rate to maintain the power output.

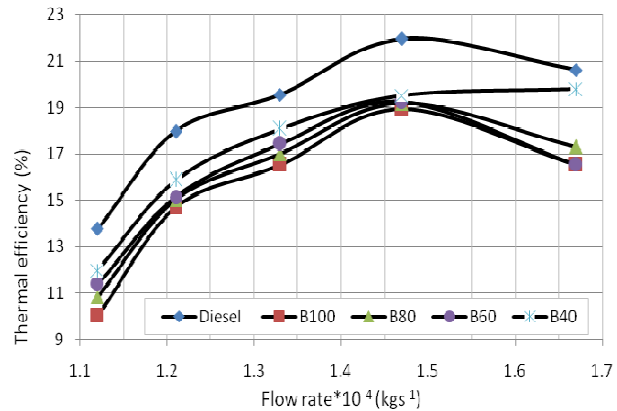


Fig. 4 Variation of thermal efficiency with fuel flow rate

Fig. 4 shows the relation in between fuel flow rate and brake thermal efficiency (η_b) for different fuels. bsfc is a measure of overall efficiency of the engine. bsfc is inversely related with the efficiency. So, lower the value of bsfc, higher is the overall efficiency of the engine. However, for different fuels with different heating values, the bsfc values are misleading and hence brake thermal efficiency is employed when the engines are fueled with different types of fuel. From the figure, it is evident that bsfc for biodiesel is always higher and η_b is always lower than that of diesel fuel. This is because biodiesel has lower heating value than conventional diesel fuel. One other cause for lower η_b for biodiesel blends is poor atomization which is attributed to higher density and kinematic viscosity of biodiesel blends.

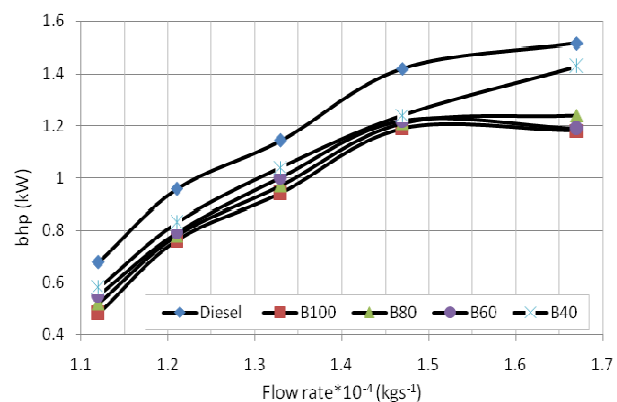


Fig. 5 Variation of bhp with fuel flow rate

Fig. 5 shows the relationship between bhp and fuel flow rate. bhp for biodiesel blends is higher at lower blend. It decreases with the increase of blend. It is also observed that bhp of engine increases with the increase of fuel flow rate.

The more fuel is consumed by the engine, the more brake power it will generate.

V. COST ANALYSIS

The present cost of running a diesel engine with biodiesel blends derived from mustard oil are given in table 9.

TABLE IV
COST FOR DIESEL AND BIODIESEL BLENDS

Fuel	Cost (Taka/ liter)
Diesel	70.00
B40	88.00
B60	100.00
B80	112.00
B100	124.00

From Table IV it is clear that, running diesel engines with biodiesel blends is costly as compared to diesel fuel. However, cost can be drastically reduced, if methanol can be recycled after transesterification reaction. Moreover, in this experiment it has been used processed coconut oil. And using raw or unprocessed oil would also cause to decrease the biodiesel production cost.

In Bangladesh, government grants a huge subsidy on diesel fuel, which causes the lower price for diesel fuel. So a thorough study is required for the feasibility analysis of biodiesel by comparing its production cost with international market price of diesel.

VI. CONCLUSION

Now a day, the developing countries are suffering greatly from energy crisis, Biodiesel can be used as a good alternative source. Although production cost of biodiesel is high but it is environmentally friendly and a good source of renewable energy. Detailed studies need to be done about the prospect of biodiesel in Bangladesh. Biodiesel production from coconut oil is comparatively higher than soybean and rapeseed. But energy output and fuel consumption rate is better than the following two. Beside this coconut oil has a much better lubrication property than other bio-fuels.

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