Biodiesel Production from Palm Oil and Performance Comparison of Diesel and Biodiesel-Diesel Blends in Diesel Engine

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ABSTRACT

Biodiesel is an alternative fuel similar to conventional or 'fossil' diesel. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil. The process used to convert these oils to Biodiesel is called transesterification. Biodiesel has many environmentally beneficial properties. The main benefit of biodiesel is that it can be described as 'carbon neutral'. This means that the fuel produces no net output of carbon in the form of carbon dioxide (CO2). The largest possible source of suitable oil comes from oil crops such as rapeseed, palm or soybean. In this paper biodiesel preparation from palm oil and its performance in diesel engine has been discussed. Early investigations report that biodiesel which is extracted from palm oil by transesterification method has similar properties like diesel fuel. Transesterification is a process of using an alcohol in the presence of a catalyst such as sodium hydroxide or potassium hydroxide to break the molecule of the raw renewable oil with glycerol as a byproduct.

Keywords: Palm oil, Transesterification, Biodiesel, Performance test

INTRODUCTION

The non-renewable nature and limited resources of petroleum fuels have become a matter of great concern. Bangladesh is an under developing country. Its energy demand is increasing day by day. Her daily demand of diesel fuel is about 109 thousand barrels [1]. The combustion of these fuels in IC engines causes pollution. All these aspects have drawn the attention to conserve and stretch the oil reserves by way of alternative fuel research. Enhanced energy security, depletion of conventional fuel and climate change mitigation are the main drivers for the transformation of the energy system from fossil to renewable sources. As a renewable energy source, the use of palm oil in diesel engines is nearly as old as diesel itself. Many researchers have found that using raw palm oil in diesel engine can cause numerous problems. Palm oil has increased viscosity, low volatility, cold flow properties and cetane number that causes injector cocking, piston ring sticking, fuel pumping problem and deposit on engine. However, the above limitations can be greatly minimized by converting the palm oil into ester through transesterification method which is named as biodiesel [2]. Biodiesel is a biodegradable, nontoxic, and clean renewable fuel with properties similar to conventional diesel. It is produced from renewable resources and has low emission profiles [3]. Biodiesel is still not commonly used in daily life mostly due to the high production cost involved, though this fuel has been developed for about three decades [4]. A cheaper raw material for biodiesel production could be a solution. The raw materials for biodiesel production now mainly include biological sources such as vegetable seed oil, soybean oil and some recovered animal fats [5]. As biodiesel is biodegradable, they do not contain any sulfur, benzene group. As a result, the products of combustion of the biodiesel do not produce. sulfur-di-oxide (SO2) and butadiene. The main advantage of using biodiesel in diesel engine is to reduce CO2 emissions [6]. At present, 100% biodiesel is not used in place of diesel fuel to run the engine.

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Because 100% biodiesel cause significant reduction of brake thermal efficiency, higher specific fuel consumptions and excessive NOx formation. This problem can be greatly minimized by using diesel-biodiesel blend. The most widely used blend is B-10. Diesel- biodiesel blend doesn't cause significant increase of NOx and reduction of brake thermal efficiency. Meanwhile the other performance parameter of the engine is like as diesel fuel [7].

Materials and Methods for Preparation of Biodiesel Methods

Vegetable oils are extracted or pressed to obtain crude oil. There crude oil usually contains free fatty acids (FFA), water, sterols, phospholipids, odorants and impurities. Using these oils in diesel engines can cause numerous problems. The increased viscosity, low volatility and poor cold flow properties of vegetable oils lead to severe engine deposits, injector coking, piston ring sticking, etc. however converting these crude vegetable oils into biodiesel may eliminate these problems. Biodiesel may be produced by following four ways:

1. Pyrolysis.
2. Micro emulsification.
3. Dilution.
4. Transesterification.

Transesterification

It is the process of using an alcohol (e.g. methanol, ethanol or butanol) in presence of a catalyst such as sodium hydroxide or potassium hydroxide to break the molecule of the raw renewable oil chemically into methyl or ethyl esters of the renewable oil with glycerol as a byproduct. Transesterification process of palm oil is given in figure 1 [8].

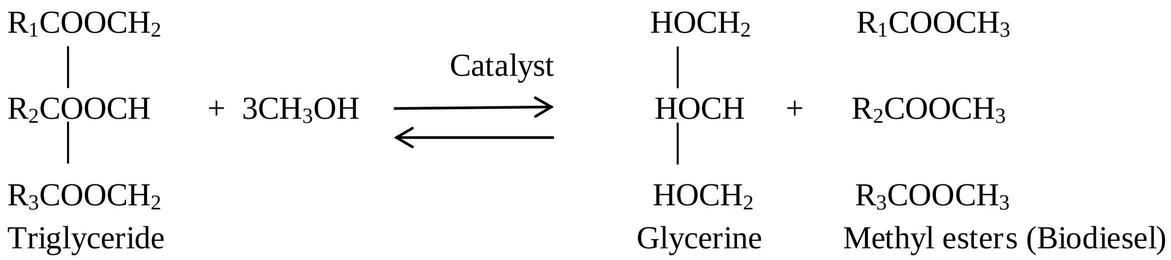

Fig1: Transesterification of fatty acid and typical chain structure of fatty acid methyl ester

The conversion of component triglyceride to simple alkyl esters with various alcohols reduces high viscosity of oils and fats. Base catalysis of the transesterification with reagents such as sodium hydroxide is preferred over acid catalysis because the former is more rapid. Transesterification is a reverse reaction. Methyl esters are the most popular esters for several reasons. One reason is the low price of methanol compared to other alcohols. Besides, esters have significantly lower viscosities than the parent oils and fats. They improve the injection process and ensure the better atomization of the fuel in the combustion chamber. Another advantage of the esters is possibly more benign emissions.

Economic of biodiesel production from palm oil

In Bangladesh it is estimated that cost of biodiesel production by transesterification process of oil obtained from palm oil will be slightly higher than that of conventional diesel fuel. 1 liter vegetable oil will be needed to obtain 1(one) liter biodiesel. After transesterification the amount of by-product in from of glycerin is up to 0.40 ml after cost analysis the following result is found.

1.	Cost of 1 liter palm oil	= 65Tk
2.	Cost of 200ml methanol(99+%purity)	= 100Tk
3.	Cost of 3.5grams NaOH	= 6Tk
4.	Total cost	= 181Tk
5.	Cost of raw glycerin	= (-)5Tk
6.	Net cost of 1 liter bio diesel	= 166Tk The cost will be reduced

substantially when it will be used in large scale.

Purpose of Transesterification

- To lower the density.
- To lower the viscosity.
- To increase cold flow properties of the oil.
- To increase cetane number (CN) of oil.

Preparation of biodiesel

Here's what we need:

- 1 liter of palm oil
- 200ml of methanol (99+%pure) Lye catalyst-3.5grams NaOH Blender machine
- Measuring beakers for methanol and oil Thermometer
- Heater

1 liter of vegetable oil (palm oil) is poured into a bowl. Then put it on the heater and let to heat. Oil is heated upto 70ºC. Then the heated oil is allowed to decrease its temperature to 55ºC. During this time, checked that the blender seals are in good order. All parts of the blender were clean and dry and that the blender components were tightly fitted.

It has measured out 200ml of methanol and poured it into 1liter container via the funnel. Methanol absorbs water from the atmosphere so did it quickly and replaced the lid of the methanol container tightly.

After that, carefully added the NaOH to the container via the funnel. The container has shaked a few times-swirled it round rather than shaking it up and down. The mixture got hot from the reaction. It has swirled it thoroughly until NaOH completely dissolve in the methanol, formed sodium methoxide.

Now heated oil is poured into the blender. With the blender still switched off, carefully poured the prepared sodium methoxide from the container into the oil. It is secured the blender lid tightly and then switched on. It is allowed to at least 20 minutes.

During the blending, the jar was covered with a wetted cloth (cold water) time by time to decrease the heat of the jar.

After completion the process, the mixture is poured from the blender into the 2 liter pet bottle for settling and screwed on the lid tightly.

Fig 2: Heated palm oil

Fig 3: Blending sodium methoxide and heated palm oil

Fig 4: Glycerin

Fig 5: B10

Fig 6: B20

Allowed it to settle for 24 hours. Darker-colored glycerin by-product collected in a distinct layer at the bottom of the bottle, with a clear line of separation from the pale liquid above, which is the Biodiesel.

Washing of Biodiesel

Biodiesel should be washed to remove soap, catalyst and other impurities. If it passes the wash-test then wash the rest of the biodiesel. For washing we have used the 2 liter PET bottles in succession, with half a liter of tap water added for each of the three or four washes required. Then we have poured the biodiesel into one of the wash bottles and added the half-liter of fresh water.Screwed the cap on tightly. Turned the bottle on its side and rolled it about with the hands until oil and water are well mixed and homogeneous.

Properties of Biodiesel

The engine performance greatly depends upon the chemical reaction between induced air and the fuel in the combustion chamber, which permits the release of heat energy. For this reason a fuel should possess a number of properties for using it in diesel engine. The main properties are given in Table 1 Properties of diesel, biodiesel and palm oil.

Name of the sample	**Density (kg/m³)**	**Viscosity (cp at 29°C)**	**Calorific value**(kJ/kg)	**Specific gravity**
Diesel	820	6	42794.64	820
Palm oil	883	22	33624.36	883
100% Biodiesel	890	7.5	35662.2	890
20% Biodiesel	851	3.9	36681.12	851
10% Biodiesel	846	3.7	37700.04	846

Engine performance, Results and Discussions

The performance of the engine at different operating conditions are given below.

Performance Parameters

Engine performance indicates the effect of a fuel in the engine. It is necessary to determine engine brake power, brake specific fuel consumption and brake thermal efficiency. The performance parameters can be calculated by following equations [9].

Engine Brake power: Engine brake power (P) is delivered by engine and absorbed load. It is the product of torque and angular engine speed where P is engine brake power in kW; N is angular speed of the engine in rpm as:

P= 2πNT

P= 60×1000

Brake specific fuel consumption: Brake specific fuel consumption (BSFC) is the comparison of engine to show the efficiency of the engine against with fuel consumption of the engine in kg/kW/hr. where (mf) is the fuel consumption rate in kg/hr. as:

Brake thermal efficiency: The percentage of brake thermal efficiency of the engine is related to engine brake power and total energy input to the engine.

Brake power× 3600

Efficiency= Fuel consumption rate× Higher calorific value

Experimental setup

The experiment is conducted with conventional diesel fuel, palm oil methyl ester. The rpm is measured directly by the tachometer. Fuel consumption is measured by a burette attached to the engine fuel. A stopwatch is used to measure the fuel consumption time for every 10 cc of fuel. The engine is electrically loaded. The full experimental setup is given in Fig 7

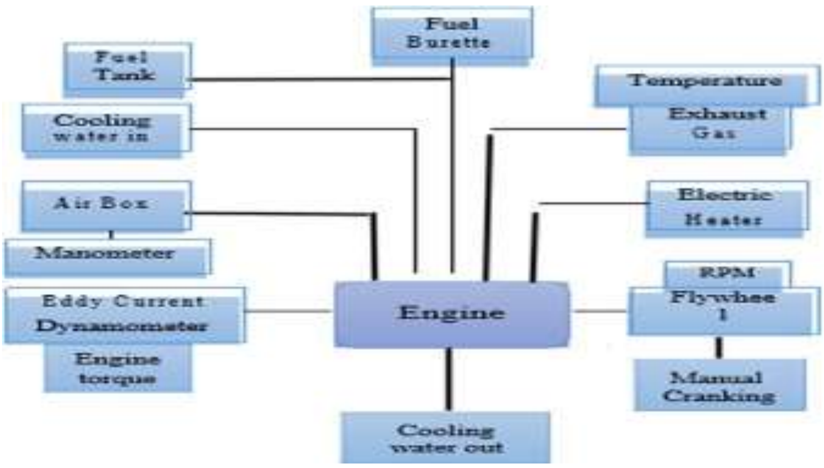

Fig 7: Schematic arrangement of experimental setup

Performance Test and Comparison with Diesel, B-20 and B-10 Brake thermal efficiency:

It is the ratio of the heat equivalent of brake power to the energy in the steam supplied per minute.

Mathematically,

Brake thermal efficiency = BP*3600/ (m_f *HCV)

Where, BP= Brake power in KW, m_f = Fuel consumption in kg/hr HCV = Higher calorific value
At 700 rpm for diesel,
When load is 3 lb then, BP = WN/4500 hp W = load = 3 lb
N = Engine speed = 700 rpm BP = 3*700/4500 = .467 hp
=.467*0.746 = .348 KW
Brake thermal efficiency = .348*3600/ (0.306*44500)
= 0.092
= 9.2 %

Effect of speed and load on thermal efficiency for Diesel fuel

Performance data of Diesel engine with diesel

Table A1

Engine speed (rpm)	700	700	700
Load (N)	0	13.35	14.69
bsfc (kg/hr/bp)	.	0.879	.924
Thermal efficiency (%)	.	9.2	8.75

Table A2

Engine speed (rpm)	800	800	800
Load (N)	0	15.58	21.36
bsfc (kg/hr/bp)	.	.799	.599
Thermal efficiency (%)	.	10.1	13.5

Table A3

Engine speed (rpm)	900	900	900
Load (N)	0	17.36	23.14
bsfc (kg/hr/bp)	.	.651	.528
Thermal efficiency (%)	.	12.42	15.3

Table A4

Engine speed (rpm)	1000	1000	1000
Load (N)	0	13.79	22.25
bsfc (kg/hr/bp)	.	.809	.519
Thermal efficiency (%)	.	9.99	15.6

Table A5

Engine speed (rpm)	1100	1100	1100
Load (N)	0	18.69	36.05
bsfc (kg/hr/bp)	.	.594	.309
Thermal efficiency (%)	.	13.6	26.14

From table A1-A5 that increasing of load and speed, brake thermal efficiency also increase.
Increasing of engine speed, fuel consumption decreases. Due to decrease of fuel consumption, brake thermal efficiency increases.

Effect of speed and load on thermal efficiency for B-10

Performance data of diesel engine with B-10 (10% biodiesel and 90% biodiesel)

Table B1

Engine speed (rpm)	700	700	700
Load (N)	0	5.34	8.9
bsfc (kg/hr/bp)	.	2.165	1.379
Thermal efficiency (%)	.	4.41	6.92

Table B2

Engine speed (rpm)	800	800	800
Load (N)	0	5.79	12.91
bsfc (kg/hr/bp)	.	1.833	.849
Thermal efficiency (%)	.	5.21	11.24

Table B3

Engine speed (rpm)	900	900	900
Load (N)	0	9.35	15.58
bsfc (kg/hr/bp)	.	1.224	.785
Thermal efficiency (%)	.	7.8	12.16

Table B4

Engine speed (rpm)	1000	1000	1000
Load (N)	0	13.35	21.81
bsfc (kg/hr/bp)	.	.915	.605
Thermal efficiency (%)	.	10.43	15.79

Table B5

Engine speed (rpm)	1100	1100	1100
Load (N)	0	15.13	26.7
bsfc (kg/hr/bp)	.	.809	0.554
Thermal efficiency (%)	.	11.79	17.24

From table B1-B5 that increasing of load and speed, brake thermal efficiency also increase.
Increasing of engine speed, fuel consumption decreases. Due to decrease of fuel consumption, brake thermal efficiency increases.

Effect of speed and load on thermal efficiency for B-20

Performance data of diesel engine with B-20 (20% biodiesel and 80% diesel)

Table C1

Engine speed (rpm)	700	700	700
Load (N)	0	4.01	12.46
bsfc (kg/hr/bp)	.	3.084	1.012
Thermal efficiency (%)	.	3.18	9.69

Table C2

Engine speed (rpm)	800	800	800
Load (N)	0	8.01	13.35
bsfc (kg/hr/bp)	.	1.523	.9397
Thermal efficiency (%)	.	6.44	10.44

Table C3

Engine speed (rpm)	900	900	900
Load (N)	0	9.35	18.69
bsfc (kg/hr/bp)	.	1.22	.754
Thermal efficiency (%)	.	8.04	13.01

Table C4

Engine speed (rpm)	1000	1000	1000
Load (N)	0	13.35	22.25
bsfc (kg/hr/bp)	.	.978	.647
Thermal efficiency (%)	.	10.04	15.18

Table C5

Engine speed (rpm)	1100	1100	1100
Load (N)	0	15.13	28.93
bsfc (kg/hr/bp)	.	.621	.479
Thermal efficiency (%)	.	11.77	20.48

From table C1-C5 that increasing of load and speed, brake thermal efficiency also increase. Increasing of engine speed, fuel consumption decreases. Due to decrease of fuel consumption, brake thermal efficiency increases.

Conclusions:

This paper discussed the production of biodiesel from palm oil and performance study of diesel engine with diesel fuel and diesel biodiesel blends and comparison among them. The findings of this paper may be summarized as follows:

Production

- Biodiesel was prepared from palm oil by transesterification process.
- Maximum 98% biodiesel production was found at 20% methanol and 0.35% NaOH at 55^0C reaction temperature.

Performance

- Thermal efficiency of B-10 is the lowest among B-20 and diesel fuel (about 2%)
- The bsfc of B-10 is the highest among B-20 and diesel fuel (about 12%)

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