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An Experimental Analysis of Single Cylinder Compression Ignition Engine Using Coconut Biodiesel –Diesel Blend

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ABSTRACT :
Biodiesel are alternative diesel fuels usually obtained from renewable sources mainly vegetable and animal oils. It is one of the most promising alternatives fossil fuels. It can be made from various renewable sources including recycled oil and can be utilized in lieu of petroleum-based diesel. To foster market competitiveness for biodiesel, it is necessary to develop cost-effective and technically sound processing schemes, to identify related key design criteria, and optimize performance.

Oil will be extracted from coconut. The extracted oil will be blended with diesel to produce biodiesel and characterized.

The purpose of this research is to develop a three steps biodiesel production from coconut oil. Special attention is paid to optimize the first step i.e., acid catalyzed hydrolysis to convert the coconut oil into high free fatty acid oil (83.32 wt %). The second step is acid hydrolysis, to produce high free fatty acid oil. The optimum condition in acid hydrolysis is 5 % by mass of hydrochloric acid in order to produce high free fatty acid oil that could be used as raw material for biodiesel production.

The third step is acid esterification, in order to reduce the FFA and convert FFA to methyl ester. It is proposed to conduct experiment in 4 stroke diesel engine and evaluate its parameters i.e. brake thermal efficiency, brake power, brake specific fuel consumption and emission characteristics.

Keywords: biodiesel, 4-stroke diesel engine, coconut oil, break thermal efficiency, break power, break specific fuel consumption, fatty acid oil and engine performance.

1 INTRODUCTION:

The reduction of greenhouse gas (GHG) emissions has become an important driver for the spread of the concept of bioenergy, in particular for Countries belonging to the Organization for Economic Cooperation and Development (OECD). Bioenergy derives from biological materials, and it is renewable as almost all can be traced back to energy from sunlight.

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Indeed, a substance used for bioenergy production is called a feedstock, as it can be converted into a biofuel in liquid or gaseous form. Examples comprise straw, sugarcane, wood waste, manure, and many other by-products form agricultural processes. Biomass feedstock can be used in different ways, e.g. by burning wood for heat, or as genetically modifying bacteria to create cellulosic ethanol. However, it is important that bioenergy is harnessed in a sustainable way.

The compression ignition engine or diesel engine is the type that has most commonly been used for power generation, particularly in off-grid situations. The engine uses a higher compression ratio than a spark ignition engine to heat air in the engine cylinder. Fuel, normally diesel which is more dense than gasoline, is then introduced and ignites spontaneously. The high compression ratio leads to higher efficiency but diesel engines must be stronger, and therefore heavier to contain the higher pressure. This makes them more expensive. The engines also produce greater quantities of some emissions than spark ignition engines. Some engines increase efficiency further by using turbochargers or superchargers. Most diesel engines are four stroke but some very large, slow-speed diesel engines are based on a two-stroke cycle.

It is found out that coconut biodiesel can combust properly above 500^0C in a compression ignition diesel engine. That coconut-based biodiesel would have shorter ignition delay, equivalently close to diesel at this temperature. The shorter combustion delay will avoid carbon deposition on the nozzle and piston valves as well as reducing the formation of NOx and CO. Other researchers found different emission results from their experiments using coconut biodiesel blends. Investigated the utilization of coconut biodiesel blends B5 and B15 in a one cylinder 4-stroke diesel engine at various throttle settings. Both biodiesels produced higher exhaust gas temperatures and decreased CO emissions with a slight increase in NOx compared to CDF. Using the same type of diesel engine, colleagues studied coconut biodiesels of B15 and B20 at different injection timings. Their experimental results indicated that NOx formation was on average 8% and 12% less than that of diesel for the B15 and B20 blends, respectively.

A fuel oil burner is a mechanical combustion machine that combines fuel oil with air in the proper amount before delivering the mixture to the ignition point in a combustion chamber.

The combustion of this mixture produces heat for application in industrial boilers to generate electricity and heater systems in buildings. The interest in oil burner technology is re-emerging due to the increase of fuel prices and the need to utilize waste oils, expand renewable fuels, and provide operational assurance against curtailments and fuel shortages. Despite the different findings and different methods used by researchers to obtain the combustion and emission characteristics of biodiesel, study on the utilization of CME biodiesel can be done extensively using an industrial oil burner rather than a diesel engine, as reported by other researchers. The combustion and emission from the utilization of CME biodiesel at low blend ratios of B5, B15, and

B20 were investigated as a preliminary evaluation of the suitability of applying this fuel in an oil burner at different fuel to air conditions. The combustor wall temperatures and exhaust emission concentrations from burning these biodiesel blends were compared with that of CDF.

2 LITERATURE REVIEW:

The works done by different authors on biodiesel fuels has been reviewed. The details about the works are specified as follows:

Atishey Mittal, etal [1], Nonconventional energy source is one of the fast growing science in which the biodiesel is one of the method of utilizing nonconventional energy sources. Paper deals with the science of biodiesel technology. Process of biodiesel production is consists of several chemical mechanisms. And the process of transesterification for different experiments and their final conclusion is taken for review. During the review of papers, experimental parameters like Engine performance parameters namely brake power, brake specific fuel consumption, brake thermal efficiency and exhaust emissions of CO, HC, NOx, and smoke density were analysed from studies carried out for different loading conditions and at constant engine speed of at different speeds. The test result indicates that there is an increase in brake thermal efficiency and slightly decrease in specific fuel consumption for all the blended fuels when compared to that of diesel fuel.

Md A. Hossain, etal [2], 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 nonrenewable, 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.

Muhammad Syahiran Abdul Malik, etal[3], presented an investigation on the combustion performance of different Coconut Methyl Ester (CME) biodiesel blends with

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Conventional Diesel Fuel (CDF) under B5 (5% CME, 95%CDF), B15 (15% CME, 85% CDF), and B25 (25% CME, 75% CDF) conditions. The performances of these fuels were evaluated based on the temperature profiles of the combustor wall and emission concentration of Oxides of Nitrogen (Nox), Sulphur Dioxide (SO_2), and Carbon Monoxide (CO).The fuel properties of the CME biodiesel blends were measured and compared with CDF. All tested fuels were combusted using an open-ended combustion chamber at three different equivalence ratios, i.e., lean fuel to air mixture (F = 0.8), stoichiometry (F = 1.0), and rich fuel to air mixture (F =1.2),using a standard solid spray fuel nozzle. The results indicated that CME biodiesel blends combust at a lower temperature and produce less emission in comparison with CDF for all equivalence ratios. Moreover, the increase of CME content in biodiesel blends reduced the temperature of the combustor wall and the emission concentration. Results also proved that the utilization of biodiesel is beneficial to various industrial applications, especially in the transportation sector due to it being environmentally friendly, and serves as an alternative to petroleum diesel fuel.

A.M.Liaquat, etal [4], Alternative fuels have received much attention due to the depletion of world petroleum reserves and increased environmental concerns. Thus processed form of vegetable oil (Biodiesel) offers attractive alternative fuels to compression ignition engines. The present work investigates the engine performance parameters and emissions characteristics for direct injection diesel engine using coconut biodiesel blends without any engine modifications. A total of three fuel samples, such as DF (100% diesel fuel), CB5 (5% coconut biodiesel and 95% DF), and CB15 (15% CB and 85% DF) respectively are used. Engine performance test has been carried out at 100% load, keeping throttle 100% wide open with variable speeds of 1500 to 2400 rpm at an interval of 100 rpm. Whereas, engine emission tests have been carried out at 2200 rpm at 100% and 80% throttle position. As results of investigations, there has been a decrease in torque and brake power, while increase in specific fuel consumption has been observed for biodiesel blended fuels over the entire speed range compared to net diesel fuel. In case of engine exhaust gas emissions, lower HC, CO and, higher CO_2 and Nox emissions have been found for biodiesel blended fuels compared to diesel fuel. Moreover, reduction in sound level for both biodiesel blended fuels has been observed when compared to diesel fuel. Therefore, it can be concluded that CB5 and CB15 can be used in diesel engines without any engine modifications and have beneficial effects both in terms of emission reductions and alternative petroleum diesel fuel.

Nicholas, etal [5], The use of biodiesel in running diesel has been called for, with a view to mitigating the environmental pollution, depletion, cost and scarcity associated with the use diesel in running diesel engine. So the need to characterize the emissions from these biodiesel, cannot be overemphasized, hence this paper presents the evaluation of the emissions of particulate matter (PM), carbon monoxide(CO), hydrocarbon(HC) and oxides of nitrogen(NOX) from diesel engine run on coconut oil biodiesel, its blends and diesel for comparison. The result of the evaluation

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showed that NOX emission increased with increase in percentage of the biodiesel in the blend, while PM, CO, HC decreased with increase in the percentage biodiesel in the blend. In comparison with diesel, diesel has the least emission of NOX and the highest emission of PM, CO and HC.

3 Fuel Properties:

3.1 Fuel Blends and Physical Properties:

CME was mixed with CDF to produce B5, B15, and B25 biodiesel blends. A sample of each fuel blend was taken to test its physical properties in terms of density at 15 ◦C, kinematic viscosity at 40 ◦C, Frictional loss at 15 ◦C, and gross calorific value. The volume and properties of diesel, CME, and their blends (B5, B15, and B25) are given in Table 1.

Table 1.1. The fuel properties of Conventional Diesel Fuel and CME biodiesel blends.

Properties	Standard	Unit	Fuels			
			CDF	**B10**	**B15**	**B20**
CME Volume		L	0	0.5	1.5	2.5
Diesel Volume		L	10	9.5	8.5	7.5
Density at 15 ◦C	ASTM D941	kg/m^3	905.1	912.0	931.5	934.3
Kinematic Viscosity at 40 ◦C	ASTM D445	mm^2/s	3.5018	3.4678	3.3600	3.2594
Frictional Loss	ASTM D971	N/m	0.289	0.29	0.35	0.45
Gross Calorific Value	ASTM D240	kJ/kg	45,290	44,734	43,891	43,136

3.2 Kinematic Viscosity:

Kinematic viscosity is a measure of fluids internal resistance to flow under gravitational forces. It is determined by measuring the time in seconds, required for a fixed volume of fluid to flow a known distance by gravity through a capillary within a calibrated viscometer at a closely controlled temperature. Here in this work Redwood Viscometer 1 and 2 are used for measuring viscosity of fuel blends, from constants obtained from viscometers kinematic viscosity is obtained.

3.3 Calorific Value :

Calorific value of the fuel is the amount of energy released or produced when one kg of fuel is burnt completely in the presence of oxygen. Here in this work bomb calorimeter is used to find out calorific values of diesel, ethanol and cotton seed oil biodiesel.

3.4 Flash Point:

Flash point is an important property of CI engine fuel. Flash point for diesel, biodiesel and their blends. it is observed that flash point of B10 have about 1.25% higher than fossil

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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 B15 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 B20, 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.

3.5 FirePoint:

Fire point is an important property of CI engine fuel. Fire point for diesel, biodiesel and their blends. it is observed that fire point of B10 have about 1.25% higher than fossil diesel, and it attains same fire point as that of diesel fuel at 55° C. So preheating at this temperature is necessary for using it in CI engine. Similarly fire point of B15 has 1.35% higher than that of diesel fuel. And at temperature 60° C, it attains the same fire point as that of diesel fuel. For fire point of B20, it has about 1.5% higher than diesel fuel, and it requires preheating at 65° C to attain similar fire point as that of diesel fuel. The fire point of the bio fuel is higher with higher blending of biodiesel. Fire point of a fuel is the lowest temperature at which the vapor of the that fuel will continue to burn for at least 5 seconds after ignition by an open flame. Fire point is usually greater than flash point. In the present work Cleveland open cup tester, 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.

4 EXPERIMENTAL SET-UP

Experimental work is carried out on a variable compression ratio (VCR) diesel engine with a single-cylinder, Power 3.5 kW @ 1500 revolutions per minute (constant speed). The overview of temperatures and fuel consumption after conduction of the test which says the performance on engine with fixed compression ratio (CR 18) at variable loads by using the diesel blends (B10, B15, B20) with coconut oil biodiesel.

Figure 1.1: Schematic diagram of Single Cylinder Kirloskar Engine.

Figure 1.2: Details of Single Cylinder Kirloskar Engine

5 Results & Discussion:

5.1 Break thermal efficiency :

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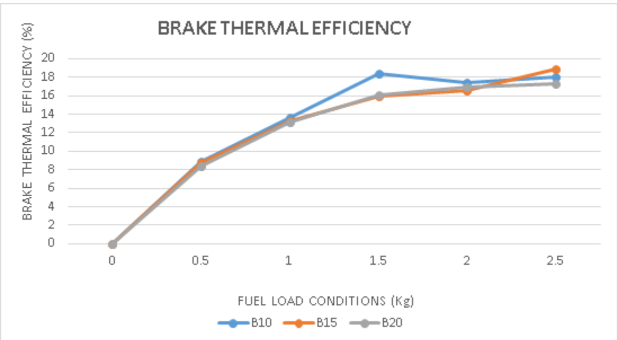
The brake thermal efficiency indicates how well an engine convert heat energy from the fuel to the mechanical energy. It is also defined as brake power of heat engine as function of thermal input from the fuel. It was observed that brake thermal efficiency increases with increase in the load. This is due to increase in power developed and reduction in heat losses with increase in load. Brake thermal efficiencies of the fuel blends COB10 D90, COB15 B85, COB20 D80 has been increased up to 1 to 2% at all load conditions when compared with conventional diesel fuel. This increase in efficiencies is due to the presence of optimum level of oxygen in the coconut oil biodiesel which will contribute to proper combustion.

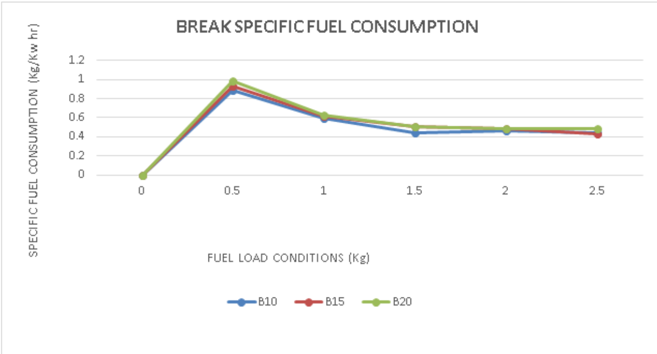
The break thermal efficiency an increase of the bsfc efficiency with increase in the engine load as the amount of diesel in the blend increases. Even a small quantity of diesel in the blend improves the performance of the engine 20 % of the biodiesel blend the thermal efficiency is very much comparable with the diesel fuel. In general, the thermal efficiency of the diesel increases with the load and the break horse power of the engine.



5.2 Break specific fuel consumption:

The consumption of fuel to generate the power in unit time is determined as brake specific fuel consumption and termed as crucial factor for any given engine. It is typically used for comparing the efficiencies of internal combustion engines with a shaft output. The brake specific fuel consumption decreases with increase in load for all the blends and increases with increase in % of biodiesel in the fuel blend. It was found in present work Bsfc decreased for all mixed blends when compared with diesel. This may be due to the optimum % of oxygen present in the blend, which might give better combustion in addition to optimum viscosity (lacking with neat diesel), leading to reduced fuel consumption. Oxygen in the coconut oil biodiesel which will improve combustion.

The load and power increases the bsfc also decreases and it is having slightly low bsfc then the diesel in all the three percentages (10%, 20%, 30%) of the blends of the biodiesel hence diesel will take more fuel to produce 1KW of power then the biodiesel blend.



5.3 Gaseous Emission:

Gaseous emissions such as NOx, SO2, and CO are toxic emissions that are harmful to the

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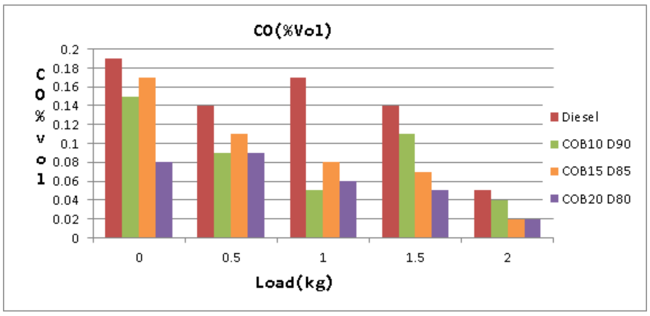
environment and human health at high concentrations. Hence, it is important to identify the emissions from the combustion of coconut oil-based biodiesel blend to determine its suitability as a replacement for fossil fuels. This section provides the comparison of emission concentrations for CME Coconut Methyl Ester blends with CDF Coconut Diesel fuel at all equivalenc

5.4 CO Emission :

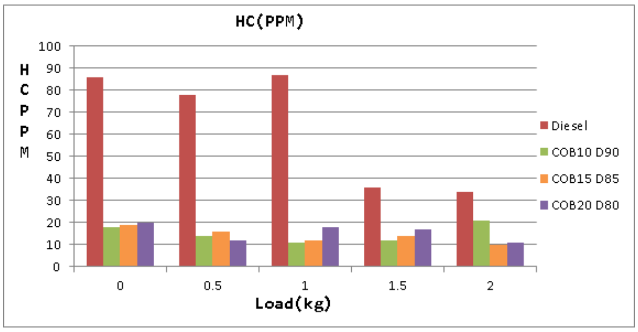
With the increase in the load the CO emission increase and diesel have a great CO then that of the biodiesel blend and 10% and 20% of the diesel blend produces the best result it indicates that the combustion efficiency improves with the blend of coconut oil with diesel. The combustion rate and hence the reduction in the carbon monoxide emission with the addition of the diesel to coconut oil improves as compared to neat diesel.

The emission of CO for CDF and CME blends for each equivalence ratio. At Φ = 0.8, by increasing the equivalence ratio, CO emission decreases to reach its lowest value at stoichiometric conditions (Φ = 1) and then rises sharply in rich conditions (Φ > 1). At stoichiometric conditions (Φ = 1), CDF produces 21 ppm of CO emission, followed by CME B10 and B15 at 2 ppm and CME B20 at 1 ppm, resulting in a 90.48% reduction for CME B10 and CME B15 and a 95.24% reduction for CME B20. CO emission concentration is highest during an incomplete combustion of fuel in a low oxygen environment. The fuel rich mixture conditions during combustion promote higher formation of CO due to high fuel consumption and inadequate air supply. The increasing content of CME in diesel fuel reduces the CO emission significantly as biodiesel contains between 10 to 12 percent more oxygen than CDF. In biodiesel, the extra oxygen content promotes the conversion of CO to CO_2, resulting in complete combustion of the fuel.



5.5 HC Emission:

The unburnt hydrocarbons also referred as hydro carbons (HC) are the results of incomplete combustion of the fuel. When the combustion takes place there will be some of unburnt fuel where the flame will not reach due to this emission of unburnt hydrocarbons will take place. There is significant reduction in unburnt hydrocarbons using coconut oil biodiesel and diesel (COB15 D85, COB20 D80) blends and coconut oil biodiesel, when compared to conventional diesel fuel. The HC emission of the coconut biodiesel blend with the diesel will have the almost the same results. The three blends have approximately same HC emission during the testing as the load increases on the engine.



5.6 NO Emission:

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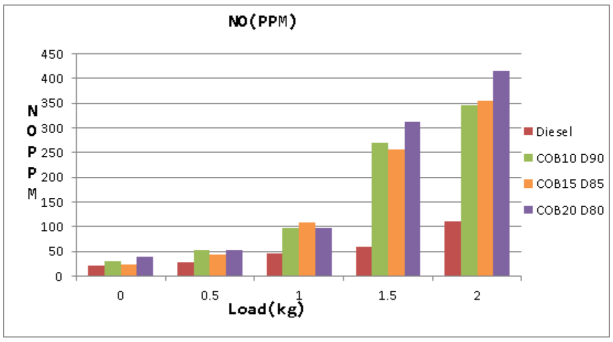
The oxides of nitrogen emitted from the diesel engines are in the form of NO and are oxidized to NO2 within short time. Approximately 10 to 20% of nitrogen oxides from diesel engine are emitted as NO2(nitrogen oxide) which is five times more toxic than NO. Nitric oxide (NO) and nitrogen dioxide (NO2) are collectively called as oxides of nitrogen (NOx). Nitrogen oxides are produced when the nitrogen reacts with excess oxygen at high temperatures. As the blends of coconut oil biodiesel and diesel (COB10 D90, COB15 D85, COB20 D80) and coconut oil biodiesel, there is a significant increase in the amount of oxides of nitrogen for all the mixed fuel blends when compared to diesel. NO concentration decreases as the amount of coconut oil in the blend goes up this reduction in NO with coconut oil operation is due to the less intensity of premixed combustion compared with diesel. The increase in NO is due to good mixing rate of fuel and air which leads to an increase in the premixed combustion.



5 CONCLUSION:

In this experimental study, the effect of coconut oil biodiesel and diesel, and coconut oil biodiesel, blends are used for investigation of performance and exhaust characteristics. The performance characteristics are done along with the diesel fuel and the results obtained fuel blends are compared with diesel fuel. The following conclusions are made

1. For the fuel blend coconut oil biodiesel and diesel (CO B20 D80), brake thermal efficiency is displayed at 80% load conditions is recorded as 18.4% which is 1% better than conventional diesel fuel.

2. At 80% of load, the brake thermal efficiency of the biodiesel fuel coconut oil and diesel (CO B15 D85) is recorded as 19.6 % which is 2% higher than conventional diesel fuel. This is due to the concentration of fuels in mixed biodiesel blend and rich content of oxygen in the fuels. Brake thermal efficiencies of fuel blends have been increased when compared to diesel fuel at all loading conditions.

3. Low brake specific fuel consumption is observed for all mixed fuel blends when compared to diesel fuel, which states that as the load increases complete combustion takes place, which assists in low fuel consumption and power produced is maximum.

4. Emissions CO, HC are significantly reduced for all mixed fuel blends at all loading conditions when compared to diesel fuel. NOx emissions are increased for all mixed fuel blends at all loading conditions when compared to diesel fuel.

- For all equivalence ratios, the CME biodiesel blends combust at lower temperatures than CDF.
- An increase in CME content reduces the combustion temperature.

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- An increase in the fuel consumption results in a decrease in the air volume, which generates more heat energy during the combustion.

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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