Evaluation of Engine Performance on Biodiesel from Waste Cooking Oil

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ABSTRACT

Economic development in developing countries has led to huge increase in the energy demand. In India, the energy demand is increasing at a rate of 6.5% per annum. The crude oil demand of country is met by import of about 70%. Thus the energy security has become key issue for our country. Biodiesel, as an ecofriendly and renewable fuel substitute for diesel has been getting the attention of researchers all over the world. The research has indicate that upto B20, there is no need of any modification.

Present study deals in the preparation of biodiesel from waste cooking oil, obtained from Indian Institute of Technology Roorkee Bhawan messes. The performance evaluation of diesel engine has also been carried out using that biodiesel upto B100. and it is found that brake specific fuel consumption for B100 (411 g/kWh) is about 17.8 % higher than diesel (349 g/kWh) at full load while the brake thermal efficiency of waste fried oil methyl ester (24.2 %) is almost similar to diesel (24.5 %) at full load without any modification in the engine design.

Keywords: Biodiesel, Waste Cooking Oil, Diesel Engine, Methyl Ester, BSFC, Brake Thermal Efficiency.

1. INTRODUCTION

With the rise in concern for pollution caused by fossil fuels such as petroleum, coal and natural gas, and the realization that energy supplies are not infinite, alternative fuels and renewable sources of energy such as biodiesel are being considered worldwide. Fossil fuel use in transportation is the leading contributor to urban air pollution and to global warming. In recent years, new sulfur and aromatic compound limits give the petroleum producers a new challenge to lower the sulfur and aromatic content of traditional fuel. Renewable fuel sources such as biodiesel and ethanol can play a modest role in reducing greenhouse gases and other potentially hazardous emission related to fossil fuels. Renewable fuels such as biodiesel are potential contributors to solving the energy problem. Biodiesel, which consists of fatty acid esters derived from vegetable oil, waste oils or animal fat in a process called transestenfication, is a renewable energy source.

Biofuels, are produced from biomass such as trees, grasses, microalgae, food-processing waste, forestry and agricultural residues, and municipal solid wastes [1,2]. The use and research of biodiesel as an alternative fuel for the diesel engine started because of the reduction of petroleum production by OPEC and the resulting price rise [3]. It is described as an alternative fuel, which improves environmental conditions and makes a certain contribution to gaining energy sustainability [4]. The use of blends with 2–30% fossil diesel fuel does not require any modification of the car engine. According to the EN 590 [5] diesel fuel standard, diesel fuel may contain up to 5% (v/v) of FAME complying with EN14214 [6]. Higher blend levels, such as B50 or B100, require special handling and fuel management and may require equipment modifications such as the use of heaters or changing seals and gaskets that come in contact with the fuel to those compatible with high blends of biodiesel [7,8]. Exhaust emissions from biodiesel engines have been reported in numerous studies [9–20]. For example, a study by Dorado et al. [12] showed that the use of biodiesel resulted in lower emissions of CO, CO_2, NO, and SO_2, but an increase in emissions of NO_2.

Biodiesel is usually produced from food-grade vegetable oils that are more expensive than diesel fuel. Therefore, biodiesel produced from food-grade vegetable oil is currently not economically feasible. Waste cooking oils, restaurant grease and animal fats are potential feedstocks for biodiesel.[21]. Yu et al. [22], Yasufumi et al. [30] Ya-fen Lin et. al. [31], & Merve C et. al. [32] compared the combustion characteristics of waste cooking oil with diesel as fuel in a direct injection diesel engine. In terms of emission, the waste cooking oil produced higher levels of CO, NO, and SO_2. Many researchers have studied the influence of physical and chemical properties of biodiesel fuels in a direct injection compression ignition engine and shown lower SO_2 and smoke concentration. They also found that fuels with higher cetane index gave a lower NO_x, HC, CO, HCHO, CH_3CHO, and HCOOH [23,24,25,26,27,28,29].

The goal of this study is to produce biodiesel from waste cooking oil obtained from Indian institute of technology

Table 1. Waste oil production data of institution messes

S.No.	Name of bhawan Mess	Student capacity (nos.)	Oil consumption (liters/month)	Waste cooking oil produced (liters/month)
1	Cautley	380	350	17.5
2	Ganga	500	460	23
3	Rajendra	535	500	25
4	Ajad	311	300	15
5	Ravindra	402	380	19
6	Govind	480	450	22.5
7	Jawahar	391	360	18
8	Sarojani	360	340	17
9	Casturba	80	75	3.75
10	Total	3439	3215	160.75

roorkee messes. Also various tests have been conducted to check the properties of waste cooking oil and biodiesel produced with the same.

2. MATERIAL & METHODS

FFA contents of cooking oil increased by heating it again and again therefore after a limit of heating that cooking oil becomes dangerous for health. That remaining oil which is not suitable for health is known as waste cooking oil. That waste cooking oil fed to drains and nallahs which causes waster pollution. Therefore an idea is being thought to convert this waste cooking oil into biodiesel using transesetrification reaction. As the institution mess is a large consumer of vegetable oil or the preparation of food for the institution students, a study has been carried out for the preparation of biodiesel from the waste cooking oil from the institution mess. There are 9 messes in the institution. The data is given in the table 1. Therefore from table 1, the total waste fried oil produced per month is 160.75 liters. Based on this data yearly consumption of cooking oil is 1929 liters. Now by considering the data obtained from experimentation done in the lab, the yield of biodiesel is 90%. Therefore the biodiesel produced from waste cooking oil obtained from the institution messes will be 1736.1 liters per year.

Production of biodiesel

Since the FFA contents of waste cooking oil collected from IIT roorkee mess are high (22%), a two step process, i.e. , acid catalyzed esterification followed by based- catalyzed transesterification process were selected for converting waste cooking oil into methyl ester. The first step, i.e., acid catalyzed esterification is for the reduction of FFA to 1%, which is mainly a pretreatment process, used to reduce the FFA. An optimum temperature of 50^0C was reported to get complete FFA esterification. The process used H2SO4 as acid catalyst. Onces the FFA contents in waste cooking oil reduces to 1-2%, the base catalyst transesterification is applied to get biodiesel.

The experimental work done using two step transesterification is being described as follows:

Acid pretreatment step: Before the actual process get start, the waste cooking oil collected from the institution mess is purified and heated at 100^0C to evaporate all the water contents from the oil. Now, the purified waste cooking oil is pored into the reactor and heated. The mixture of concentrated H2SO4 (1% of the oil amount) with methanol is heated at 50^0C and then added into the reactor. Different methanol to oil ratios (w/w) were used (6:1, 8:1, 10:1)to investigate their influence on the acid value of waste cooking oil.the acid value of the reaction mixtures were measured using standard method while the composition of the reaction mixture were determined using gas chromatography(GC). After 3 hour reaction the mixture is allowed to settle for 2 hrs. The optimum condition having lowest acid value was used for the main transesterification.

Base catalyzed transesterification: In the second step, optimum condition for NaOH to oil ratio and methanol to oil ration were investigated. Firstly, the pretreated oil obtained from the first step was poured into the reactor and heated at 50°C. The solution of NaOH in methanol at 0.5%, 1.0%, 1.5%, 2.0% and 3.0% (w/w) of the oil were heated to 50°C prior to addition and then added to the heated oil. The reaction mixture was heated, refluxed and stirred again at 65.0±0.5°C and 400 rpm for 2h. The mixture was allowed to settle for overnight for separating the heavier glycerol layer from the lighter methyl ester layer of fatty acids. The methyl esters were checked by GC. The same procedure was conducted for the investigation of optimum methanol to oil ratio. The investigation was carried out by using optimum NaOH in various methanol to oil ratio (w/w) at 0.1, 0.2, 0.35, 0.5 and 0.6.

3. PERFORMANCE EVALUATION OF IC ENGINE USING BIODIESEL PRODUCED FROM WASTE COOKING OIL

In order to study the performance of IC engine using biodiesel and its blends with diesel, an experimental study has been carried out. The efficiency and brake specific fuel consumption (BSFC) of the engine was measured under variable load conditions for different blends.

Experimental procedure

The engine was directly coupled with 2KVA alternator and loaded by electrical resistance. The separate fuel measurement unit was connected with engine. A resistive load panel was attached with the output of the generator. The engine- generator set was run initially using diesel for 10 minutes at each part load of 25%, 50%, 75% and 100% of 2 kW respectively. At each case, the rpm of the generator was maintained at 1500. The fuel consumption at each case was measured by using stopwatch. At the same time the reading of voltmeter, current meter and energy meter were also noted down. Different blends of biodiesel from waste cooking oil with diesel were prepared namely B10, B20, B30, B40, B50, and B100.Before using blend, each one was mixed thoroughly. Then in the similar manner as in case of diesel fuel reading of each meter is noted down. During each blend, the filter of diesel engine was opened and complete mixture of biodiesel and diesel was drained so that it could not impure next blend by mixing with its previous blend. Then again for another blend, in the similar fashion, the experiment was repeated for knowing the above stated parameters. In this way continuously one month, the experiments were performed for all type of blends as stated above.

4. RESULTS AND DISCUSSION

During the reaction the samples of esterified oil were taken at the interval of 15min and then samples were analysed for biodiesel yield using gas chromatography. The results of methyl ester yield with time are shown in fig.1.

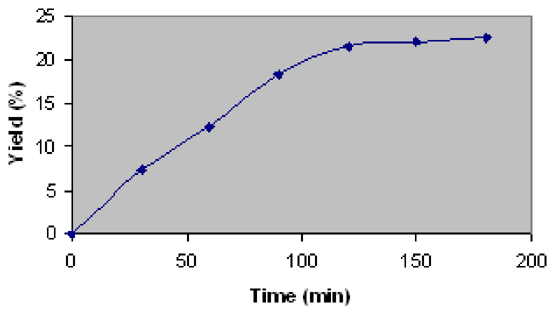

Fig. 1. Graphical representation of Methyl ester yield with time in case of acid transesterification

Samples were drawn at an interval of 15 min upto 200min and then checked in GC to determine the yield of biodiesel produced. The results are shown in fig.2.

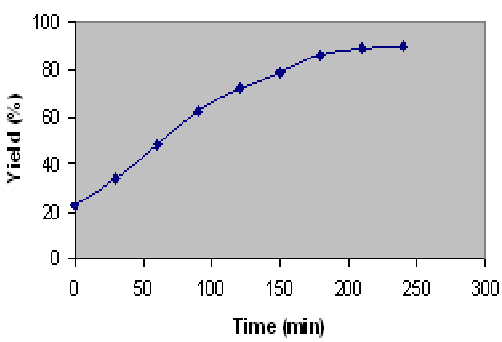

Fig. 2. Graphical representation of Methyl ester yield with time in case of base transesterification

Data of fig.2 indicates that a maximum of 90 % yield of biodiesel could be obtained in 200 hrs beyond which the yield is decreases.

Properties of biodiesel

To check the properties of biodiesel produced from waste cooking oil of institution messes, various tests were conducted. And the properties obtained are compared with diesel in table 2.

Table 2. Properties of biodiesel

Properties	**Waste cooking oil**	**Biodesel**	**Diesel**
FFA (%)	21	0.87	0.8
Calorific value (kJ/kg)	34560	35640	42000
Density	937	892	880
Viscosity	50	4.2	2.6

Brake specific fuel consumption

The Brake specific fuel consumption is defined as the fuel consumed by engine in gm for per kW per hour. In order to assess the out power at the engine shaft end, the efficiency of generator is taken as 90%. The Brake specific fuel consumption for different fuel at different load is reported in fig. 3.

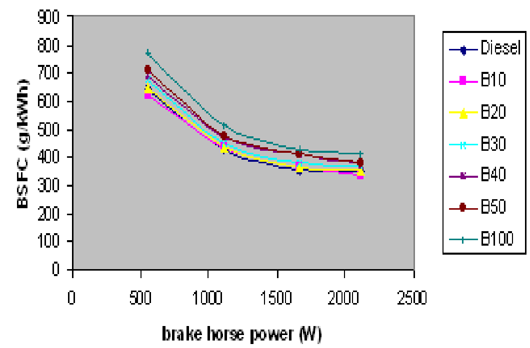

Fig.3. Variation of BSFC for different fuels with load

The brake specific fuel consumption (g/kWh) decreases as the load increases for all type of fuel combination. The reason behind that may be , at high load, the cylinder wall temperature get increased, which reduces the ignition delay.thus, shortening of ignition delay improves combustion and reduces fuel consumption. The trend of BSFC for different blends of neat biodiesel at different loads is given in fig. 3. which indicates that the higher BSFC for B100 (411 g/kWh) is about 17.8 % higher than diesel (349 g/kWh) at full load.

Brake thermal efficiency

The Brake thermal efficiency is defined as the ratio of output energy available at the engine shaft to the input energy given to the engine. The brake thermal efficiency for different fuels at different loads is given in fig. 4.

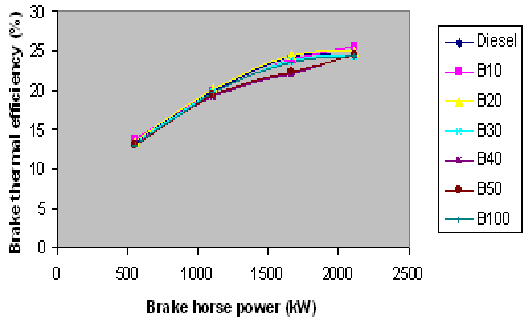

Fig.4. Variation of brake thermal efficiency for different fuels with load

The variation of brake thermal efficiency is shown in fig.4 , which indicates that the brake thermal efficiency of waste fried oil methyl ester (24.2 %) is almost similar to diesel (24.5 %) at full load . The brake thermal efficiency for biodiesel for all blends range (B10-B100) was fond almost comparable to efficiency of diesel fuel. It indicates that higher cetane number and inherent presence of oxygen in the biodiesel produced better combustion. The brake thermal efficiency for B10 (25.6 %) was about 1.1 % higher than diesel, however it was 0.5 % higher for B20 (25 %) than diesel. The reason for higher efficiency up to B20 may be because of better combustion due to inherent oxygen and higher cetane number. Beyond B20, the lower calorific value and higher viscosity might be dominating factor over inherent oxygen and higher cetane number. Due to higher viscosity, the automization of fuel will not be as good as it will be for lower viscosity at the same level of pressure developed by injector pump.

5. CONCLUSIONS

The present study dealth with the production and utilization of biodiesel from waste fried oil obtained from IIT Roorkee messes. The effect of various parameters on engine loading was evaluated. Based on the resulys, the following conclusion can be drawn:

1. The biodiesel produced from waste cooking oil obtained from the institution messes will be 144.675 liters per month. That can be used to run institution vehicles as well as institution DG set to supply electricity during power shade hours.

2. The brake specific fuel consumption for B100 (411 g/kWh) is about 17.8 % higher than diesel (349 g/kWh) at full load and rated rpm while the BSFC of B20 was comparable to that of diesel and this is perhaps the reason that B20 has been recommended as optimized blend by many researchers.

3. The brake thermal efficiency of waste fried oil methyl ester (24.2 %) is almost similar to diesel (24.5 %) at full load while that for B10 (25.6 %) was about 1.1 % higher than diesel, however it was 0.5 % higher for B20 (25 %) than diesel.

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