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ASSESSMENT OF FUEL PROPERTIES OF BIODIESEL FUEL FROM WASTE OIL

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ABSTRACT

The main aim of this study is to reduce the use of petroleum diesel by using domestic renewable sources such as waste oil as fuel. Ever increasing of diesel engine usage due to its higher fuel efficiency can cause severe environmental damage particularly urban areas. Rapid growth of population, urbanization and industrialization are the main factors which increase the air pollutants particularly CO_2 emission to the environment. Continuous addition of CO_2 emission to atmosphere is responsible for the formation of global warming, acid rain and cancer risks etc. Biodiesel is the primary source to solve the entire above problems. Because it is a renewable, low polluted, non-toxic, biodegradable well known alternative fuel to diesel engines. Presently most of the biodiesel fuels are produced from food grade oils only. Biodiesel from food oils can cause food oil crisis and increases the production cost of biodiesel. This will encourage the development of biodiesel from cheapest sources like non-edible oils and waste oils. Therefore present investigation was made to produce biodiesel fuel from waste oil and the important fuel properties were analyzed.

KEY WORDS: Waste oil; Environmental pollution; Biodiesel cost; Renewable; Non-toxic

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1. INTRODUCTION

Currently the major part of the energy requirement is being met out from fossil fuels (Petrol and Diesel). India is one of the largest petroleum consuming countries in the world. India imports 40 million tones of petroleum fuel per year. Due to the rapid growth of urbanization, vehicle population and industrialization needs more and more energy sources especially petrol and diesel from natural sources leading to the end of natural source is not far away. This indiscriminate extraction and usage of petroleum diesel fuel in diesel engines can cause damage of environment. In addition to this the cost of petroleum products is also increasing day by day due to over consumption of natural resources' and stiff commercial competition among the developing countries.

Biodiesel is the prominent solution to solve the entire above said problem. Because, biodiesel is a renewable, biodegradable, economically viable and low polluted alternative energy source for diesel engines. There are more than 350 oil bearing crops identified for biodiesel production, among that only Sunflower, Soy bean, Corn, Rape seed and Palm oils are considered as potential alternate source for biodiesel production. But the drawback for commercialization of biodiesel is its high cost. Raw materials used for biodiesel production occupy the major part of increasing the cost of biodiesel. Looking for the use of non-edible oils and waste oil sources for biodiesel making process is a good option to solve the food oil crisis and biodiesel cost. Therefore currently an attempt was made to produce biodiesel from waste cooking oil. Waste oil is the cheapest source which is abundantly available throughout world. Waste oil from industries and restaurants are one of the pollution in developing countries. Conversion of waste to biodiesel reduces the production cost biodiesel and it also inhibits the soil pollution and air pollution.

1.1 *Transesterification*

Transesterification is a commonly employed method for biodiesel production. In this reaction triglycerides were converted into monoglycerides and glycerol with the help of catalyst in the presence of methanol as a solvent. Transesterification process can be catalyzed by using acid catalyst or alkali catalyst or enzyme catalysts. However, alkali catalyzed transesterification method is widely applied for biodiesel making process due to its economic viability than the other method. But alkali catalyzed transesterification reaction are very sensitive to FFA content of oil samples.

Viscosity reduction is the main reason for the transesterification of vegetable oils. Direct application of unprocessed vegetable oil as fuel to diesel engines can cause several engine problems like poor combustion, engine fouling, atomization etc. Therefore the viscosity of oils can be reduced by using several methods including blending of vegetable oil with petroleum diesel, pyrolysis, microemulsification and transesterification. However, transesterification is widely accepted method for viscosity reduction.

2. MATERIALSAND METHODS

Waste oil were collected from local restaurants for transesterification process. Before the transesterification the quality of oil especially free fatty acid and water content were determined. Because poor quality oil samples is not responding for transesterification process. Presence of water and high free fatty acid content is responsible for the process of saponification. The present study material (waste oil) used for biodiesel production having high FFA content. Hence direct application of base catalyst is not possible for transesterification process. Therefore the FFA content of waste oil sample was reduced by using acid catalyst. All the reactions should be carried out in an air tightened plastic water bottle to avoid methanol evaporation and maintain the pressure.

2.1 Pretreatment

One liter of waste oil sample was preheated in a water bath at 60°c for 30 min. Mixture of acid catalyst (10 ml H_2SO_4 and 200 ml of methanol) was added to the preheated oil sample. The sample was mixed and incubated in a water bath at 60°c for 4-5 hrs. After the completion of incubation period the oil sample shows two distinct layers i.e. upper ester layer and lower glycerin layer. The upper layer was collected for further process.

2.2 Alkali catalyzed transesterification

One liter of acid treated ester layer was measured and incubated in a water bath at 60°c for 10-15 min. 7.5 g of KOH and 200 ml methanol was thoroughly mixed and poured in to heated oil sample. The sample was mixed well and incubated to water bath at 60°c for 1-2hrs. After the completion of incubation period the oil sample shows two clear layers. The upper yellow colored layer was saved and lower black colored layer (glycerin) was discarded.

2.3 Biodiesel washing

The transesterified ester layer may contain unreacted catalyst, methanol and traces of unremovable glycerol. Presence of above contaminants in ester layer is undesirable for used as a fuel. Catalyst can corrode the fuel hoses of engines; methanol reduces the flame temperature of fuel. Similarly presence of glycerol in fuel samples can plug the fuel lines of diesel engines. Hence removal of above contamination is necessary to ensure the fuel quality. Therefore, the contaminant present in ester layers were successfully removed by using water wash method. For this process equal volume of hot distilled water was added to ester, mixture was gently mixed and allowed to settle for two layers. The lower water layer having contaminants was discarded and the upper layer repeatedly washed with hot distilled water until the water layer becomes clear (Fig-2). Finally the cleared ester layer was preserved.

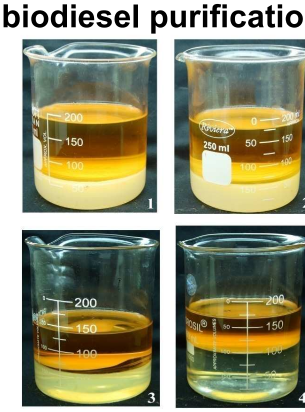
2.4 Drying

The washed ester layer may contain water content. Presence of water in ester layer is favor for the growth of biological organisms because ester is a good substrate for the growth of microorganisms. In addition to this water content may lead to increase the acid value of fuel. Hence water from ester layer should be removed by heating process. The ester was heated in a hot plate at 100 °c for 30 min to evaporate the water and methanol. Finally the dried ester layer (Biodiesel) was preserved for future fuel (Fig-1, D).

3. RESULTS AND DISCUSSION

Figure-1
Different stages of BD production from waste oil

Figure-2
Steps for biodiesel purification



(A-Waste oil; B-Acid treated oil; C-Alkali treated oil; D-Pure BD)

3.1 Quantification of waste oil BD

Table-1
Yield of biodiesel from waste oil using acid and alkali catalyst:

Source	Initial volume of oil sample	Acid catalyst	Methanol	Yield of Ester layer	Glycerol
Waste oil	1000 ml	10 ml - H_2SO_4	200 ml	1060 ml	150 ml
Source	**Initial volume of oil sample**	**Alkali catalyst**	**Methanol**	**Yield of Ester layer**	**Glycerol**
Acid treated waste oil	1000 ml	KOH	200 ml	950 ml	160 ml

After the completion of transesterification the yield of waste oil biodiesel was measured and the quantity was tabulated (Table-1). This study concludes that the acid catalyst gives maximum yield than the base catalyst (1060 ml of ester and 150 ml of glycerol was obtained in acid catalyst method where alkali catalyst gives 950 ml of ester and 160 ml of glycerol). But base catalyst gives high quality fuel than acid catalyst. Fuel quality is the primary concern in which this study recommends alkali catalyzed method for biodiesel production from waste cooking oil.

3.2 Physical property

Table-2
Comparison of important fuel properties of biodiesel from waste oil with PD

Properties	Methods	Waste oil	Waste oil biodiesel	Petroleum diesel
Viscosity 40ºC mm^2/s	D 445	42.93	3.8	1.3-4.1
Density 15 ºC g/cm^3	D 1298	920	0.86	0. 83
Calorific value MJ/kg	D 240	34.75	38	43
Flash point ºC	D 92	290	138	53
Cetane number	D 613	39.10	45	38-40
Acid value mg/KOH/g	D 664	5.68	3.4	0.22
Water content %	D 2709	-	0.02	-

The important fuel properties of waste oil and its biodiesels were analyzed using international ASTM standard method and the results are tabulated in table no 2. The properties of waste oil biodiesel fuel were compared with petroleum diesel fuel to evaluate the fuel suitability of biodiesel. The important properties will be discussed.

3.2.1 Kinematic viscosity (D 445)

Viscosity of fuel plays an important role in the combustion process of fuel since it affects the operation of fuel injection equipment particularly at low temperature. The viscosity of unprocessed waste oil, biodiesel fuel from waste oil and petroleum diesel is presented in table 2. As discussed earlier high viscosity of fuel can cause several engine related problems like severe engine deposits, piston ring sticking, injector cocking and thickening of lubricating oil[1-4]. The viscosity of waste oil is 42.93 where biodiesel from waste oil is 3.8. The viscosity range of petroleum diesel is 1.3-4.1. This severe reduction of biodiesel fuel viscosity indicates that the complete removal of glycerol from waste oil sample. Hence this study recommends transesterified waste oil may be a substitute for petroleum diesel fuel.

3.2.2 Density (D 1298)

Density is a key fuel property, which directly affects the engine performance characteristics such as cetane number and heating value[5]. Several studies observed that there is no much variation of density in biodiesel fuel, because the densities of methanol and oil are close to the density of biodiesel [6&7]. Before transesterification the density of waste oil is 920 where biodiesel from waste oil is 0.86. The density of petroleum diesel fuel is 0.83. Higher density of biodiesel fuel is the main factor for higher consumption of biodiesel fuel than Petroleum diesel fuel (PDF). However in the present investigation, the density of waste oil biodiesel is closely related to PDF. Hence this study recommends that the transesterified waste oil as a alternative fuel to diesel engine.

3.2.3 Calorific value (D 240)

The calorific value (CV) of biodiesel fuel was determined by using ASTM D 240 method. Calorific value is another essential parameter which is used to determine the energy content of fuel. Calorific value is the amount of heating energy released from the engine at the time of fuel combustion. The CV of petroleum diesel fuel (43 MJ/kg), unprocessed waste oil (34.75 MJ/kg) and its biodiesel fuel (36 MJ/kg) were represented in table 2. Waste oil biodiesel having higher CV than unprocessed oil, but it is lower than PDF. In general biodiesel fuels contains approximately 10% low energy than PDF. Presence of more oxygen content in biodiesel fuel is the main reason for this lower calorific value [8]. This lower calorific value of biodiesel fuel increases the consumption of biodiesel than PD [9&10]. There is no much difference between the biodiesel fuel and PDF this study may recommend the use of transesterified waste oil as a alternative to PDF.

3.2.4 Flash point (D 92)

Flash point is used to identify the ignition temperature of fuel. The results of flash point of processed (biodiesel fuel), unprocessed (waste oil) and PDF were presented in table 2. Normally flash points of biodiesel fuels are very higher than PDF[11]. Flash point of unprocessed waste oil (290°c) is very higher than processed one i.e. biodiesel fuel (138°c). The flash point of PDF is 53°c. Higher flash point of fuel favors the formation of carbon deposition on combustion chamber of diesel engine. But it is safe for handling process than PDF [7&12].

3.2.5 Cetane number (D 613)

Cetane number (CN) is the primary parameter to decide fuel quality. Higher CN of any fuel enhances the ignition of fuel[11]. CN of PDF, waste oil and respective biodiesel were presented in table 2. The cetane number of waste oil (39.10) is lower than waste oil biodiesel (45) and PDF (40). Transesterification process of vegetable oil improves the CN of oil sources by the maximum removal of glycerol. This higher cetane number of biodiesel fuel reduces ignition delay and longer ignition delay of fuel can cause diesel knock. This higher CN of biodiesel fuel enhances the engine performances which facilitates the reduction of pollutants except NOx. In addition to this presence of higher CN of fuel may increase the oxidative stability of fuel. On the other hand CN more than 65 is responsible for plug of injector nozzle. Similarly the lower values of CN of biodiesel can cause diesel knock and increase in gaseous and particulate emissions due to incomplete combustion of fuel [13]. However higher CN in biodiesel fuel leading to pollution reduction is desirable. Hence this study recommends the use of waste oil biodiesel as a alternative fuel to diesel engines.

3.2.6 Acid value (D 664)

Acid value is the total amount of potassium hydroxide necessary to neutralize the free acids present in biodiesel sample. Acid value can be determined by titration process using international ASTM D 664 method. Acid values of PDF, waste oil and its respective biodiesel fuel were presented in table 2. The acid value of waste oil (5.68) is higher than PDF (0.22) and biodiesel fuel (3.4). Higher acid value indicates poor quality of oil sources. Higher acid value of BD fuel can cause degradation of rubber parts resulting in the formation of filter clogging. The acid value can be improved by controlling the transesterification, cleaning and drying processes. However the acid value (AV) of biodiesel fuel depends on variety of factors. On the one hand, it is influenced by use of feedstock for biodiesel production and its respective degree of refinement. On the other hand, acidity can also be generated at the time of production process, for instance when introducing mineral acid as catalyst or by free fatty acids resulting in the formation of soap. The acid value of biodiesel fuels gradually increases due to hydrolytic cleavage of ester bonds during long time storage. The higher acidity of fuel can cause corrosion and the formation of deposits on the engine particularly in fuel injectors, by catalyzing the polymerization in hot recycling fuel loops. However weak carbolic acids have lower risks than strong mineral acids [14].

3.2.7 Water content (D 2709)

Water is a major source of fuel contamination. Presence of water content in biodiesel fuel can cause following problems 1. It can corrode the fuel system of engine. Another problem associated with water content in biodiesel is development of microbial organisms such as yeast, fungi and bacteria. Because biodiesel is a good source of food for microbes and water may help the respiration of microbe. Hence presence of water in biodiesel fuel will accelerates the growth of microbial colonies which can seriously plug the fuel system. In addition to this biodiesel having water content can cause reversion of fatty acid methyl esters to fatty acids, which can lead to filter plugging. On other hand, water content of biodiesel reduces the heat of combustion leading to more smoke, harder starting and less power. The water content in waste oil biodiesel is very less. Hence this study may recommend the use of waste oil biodiesel as a alternative fuel to diesel engines.

4. CONCLUSIONS

In the present investigation the waste oil was collected from local restaurants and it was successfully converted into biodiesel fuel using two step catalyzed transesterification process. Conversion of waste oil to biodiesel fuel can help to reduce the production cost (cheaper than PD) as well as environment pollution. The important fuel properties such as viscosity, density, calorific value, flash point, cetane number, acid value and water content of waste oil biodiesel were checked to assess the fuel suitability of biodiesel. The physical property of waste oil biodiesel is closely related to the petroleum diesel except flash point. Hence this study concluded that transesterified waste oil or biodiesel may be a better source for diesel engine operation.

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