Blending scenarios for microalgae biodiesel with waste cooking oils biodiesel, Butanol and Indian petro-diesel as an alternative fuel for diesel engines

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Abstract

Indian Ministry of New and Renewable Energy (MNRE), decided to blend at least 20% biofuels with diesel and petrol by 2017. Biodiesel has obtained from algal oils and waste cooking oil that have been considered as a promising alternate fuel.In this study, the feasibility of biodiesel production from microalgaeChlorella *singularis*and waste cooking oil has been investigated. The physico–chemical characteristics of the produced biodiesel were studied according to the standards methods of analysis (ASTM) and evaluated according to their fuel properties as compared to Indian petro-diesel. The obtained results showed that; C2+A2+B8+D88 blended biodiesel of algae and cooked oil showed that the high oxidation stability and higher load carrying. The observed properties of the blends were within the recommended petro-diesel standard specifications and they are in favor of better engine performance.

Key words: Microalgae;waste cooking oils; biodiesel; Butanol; Indian petro-diesel.

1. Introduction

The rapidly increasing energy demands is increasing the fossil fuel load. Moreover this has also lead to huge amount of carbon emissions. There is a current global need for Cheap, clean and renewable energy sources. Renewable energy technologies are clean sources of energy that have a much lower environmental impact than conventional energy technologies (Arora et al., 2016). Biodiesel is non-toxic, biodegradable, has negligible CO_2 emission nature and can be direct used in unmodified diesel engines (Lam et al., 2012).

Chlorella *singularis*, has a fast growth rate, requires uncomplicated farming and produces higher lipid and biomass content (Tang et al. 2011). *Chlorella species* display high biomass productivity, and also greater resistance to harsh conditions and invaders is an ideal as a source of proteins, enzyme, lipids, carbohydrates, pigments, vitamins and minerals (Safi et al., 2014, Ebrahiminezhad et. al., 2014, Frumento et al., 2013, Kitada et al., 2009, Jayed et al., 2009). Thus *Chlorella species* is an ideal as a source resource for producing biodiesel and blending is necessary for oxidation stability (Yee et al., 2016). The inappropriate disposal of Waste Cooking Oils (WCO) can be prevented and moreover it can be utilized by converting it into biodiesel. In the present study, Chlorella *singularis biodiesel* was blended withwaste cooked oil biodiesel, butanol and Indian petro-diesel fuel.

2. Materials and Methods

2.1 **Algae strain isolation and culture condition and lipids Extraction**

The Chlorella *singularis* strain UUIND5 (Gen Bank accession number: KY745895) isolated earlier by our group from fresh water were used in this study. Algae was grown at 25/20 ^{o}C at 16h light/8h dark photoperiodunder LED (Blue wavelength 450-495 nm). Lipids were extracted from fresh microalgal biomass using a modified method of Bligh and Dyer (1959).

2.5 **Waste Cooking Oils (WCO) samples**

The WCO samples were obtained after being used several times for frying purposes at small shops. WCO samples were collected from the restaurants and shops of theDehradun, Uttarakhand, India, with 10 ml of each and filtered to remove inorganic residues.

2.6 Biodiesel production- acid catalyzed transesterification

The total extracted lipids from microalgae were transesterified into fatty acid methyl esters (FAMEs) by methanolic sulphuric acid (6%) (Arora et al., 2016).WCO was transesterified bymethanolic KOH (0.75%) (Patel et al., 2015). The FAMEs were analyzed using gas chromatography- mass spectroscopy (GC-MS; Agilent technologies, USA). 1 μlof sample was injected and process completed according to Patel *et al*. 2015

2.7 **Preparation of blending with biodiesel, butanol and diesel fuel by Inline blending method.**

Biodiesel is slightly heavier than the diesel fuel. So that during the blending biodiesel stays on the bottom of the tank. Inline blending method has been adopted for mixing due for the suitable results and reduces the shock crystallization (BHe et al., 2007). In an Inline mixing method to prevent the crystallization, to kept the biodiesel above cloud point. In this method it is to be one with three storage tank containing biodiesel, diesel and Butanol passing through a pipe and mixed in a particular ratio and collected the blended product in the next tank.

2.8 Characterization of Biodiesel and its Blends

Density: Density of biodiesel and its blend was determined by the capillary stopper relative bottle or Pyknometer (BIS 1972)

Specific Gravity: Specific gravity of the biodiesel and its blend was determined by the specific gravity bottle at 30 ^{0}C (BIS 1964).Specific gravity of liquid is the ratio of density of a substance (Liquid) compared to the density of fresh water.

Flash Point: Pensky Marten's apparatus was used to determine the Flash point of the biodiesel and its blend.

Cloud point and Pour point: The cloud point and pour point of the biodiesel and its blend was determined with help of Cloud point and Pour point apparatus.

Kinematic Viscosity: Kinematic Viscosity of methyl ester and its blend was determined with the help of Redwood Viscometer No 1or 2 at 40 ^{0}C

Saponification value: The saponification value of methyl ester and its blend was determined by refluxing a known weight of the sample with a known excess amount of standard KOH solution.

Acid Value: The acid value of biodiesel and its blend was determined by the titrating with Alkali.

Iodine Value: The iodine value is a measure of the unsaturation of oils by using wij solution.

Aniline Point: It is determined by thoroughly mixing of equal volume of biodiesel and its blend with aniline in aniline point apparatus.

API Gravity: The API is a measure heavy or light petroleum liquid is compared to water.

Diesel Index: The ignition quality of diesel fuel is reported in terms of diesel index.

Moisture Content: The % of moisture can be calculated by Karl-Fisher method (BHe et al., 2007, ASTM D6751, 2012).

3. Result & Discussion

3.1 **Algal and Waste Cooking Oils (WCO) biodiesel composition**

The FAME composition of the produced biodiesel is shownin Table 1.The total extracted TAGs from Chlorella *singularis* UUIND5 were transesterified to FAMEs andanalyzed by GC-MS. Major fatty acids present were myristic acid (C14:0) 1.5%, pentadecanoic acid (C15:0) 0.20%, palmitic acid (C16:0) 16.19%, 7,10-hexadecadienoic acid methyl ester (C16:2) 0.15%, stearic acid(C18:0) 9.44%, oleic acid (C18:1) 13.72% and linoleic acid (C18:2) acid 18.15%.

The majorfatty acids present in WCO wereOctanoic acid (C8:0), Decanoic acid (C10:0),Dodecanoic acid(C12:0), myristic acid (C14:0), palmitic acid (C16:0), stearic acid(C18:0) and oleic acid (C18:1). linoleic acid (C18:2) acid.

3.3 **Characteristics of algal and WCO biodiesel and its blends with Butanol and Indian petro-diesel**

The results collected from the study of the physical and chemical properties of the test biodiesel sample (Table .2) as per the specification of Standard ASTM D6751(ASTM D6751, 2012).

On the basis of the above data the characterization of cooked oil and algae based biodiesel the percentage of oil content algae is less sufficient for the feedstock but it is good for the environment. The density and specific gravity of the cooked oil and algae based methyl ester is meeting with the ASTM D-6751. The kinematic viscosity of the cooked oil methyl ester is quite met with the ASTM D-6751 standards, carrying the high load capacity, increases the oxidation stability while kinematic viscosity of algae based methyl ester is quite. The high viscosity resulted in a lower oxygen diffusion rate, thus higher oxidation stability (Ikwuagwu et al., 2000). Cloud point and pour point of the cooked oil and algae based methyl ester is just similar to the ASTM D-6751 specification showing that the ideal conditions of fuel in cold and storage environment but the flash point of both the methyl ester is low shows the medium flammable conditions of fuel of diesel engine in warm and storage conditions (Gopinath et al., 2010). The obtained biodiesel was characterized by higher API (27.48) of algal biodiesel compared to that of cooked oil biodiesel (9.15). A diesel fuel is a mixture of aromatics, naphthenes and paraffins, which are the three basic types of hydrocarbons found in petroleum (Soha et al., 2013).The aniline point and diesel index of cooked oil and algae based methyl ester is good and lowers the chances of deterioration of methyl ester when the oil comes in contact with the rubber, packing etc. The Moisture content in cooked oil and algae based methyl ester is comparatively too high, affect the fuel combustion of diesel engine. The API gravity of cooked oil is less than 10, the fuel is heavier than water and sinks however the API gravity of algae methyl esteris greater than 10, the fuel is lighter than the water and floats on water. The cold flow and other properties were improved by blending. The characterization of percentage of blended biodiesel with butanol and diesel fuel (Algae biodiesel+ Butanol + Diesel)as Algae biodiesel 2% + Butanol 8% + diesel 90% (A2+B8+D90), algae biodiesel 5% + Butanol 10% + diesel 85% (A5+B10+D85),algae biodiesel 10% + Butanol 15%+ diesel 85% (A10+B15+D75),algae biodiesel 15% + Butanol 20% + diesel 65% (A15+B20+D65), algae biodiesel 20% + Butanol 25% + diesel 55% (A20+B25+D55) in table 3. The other characterization of increases the efficiency of algal biodiesel with waste cooked oil, butanol and diesel fuel (Waste cookedoil biodiesel+ Algae Biodiesel + Butanol + Diesel) as waste cookedoil biodiesel2% algae biodiesel 2% + Butanol 8% + diesel 88% (C2+A2+B8+D88), waste cookedoil biodiesel5% + algal biodiesel 5% + Butanol 10% + diesel 80% (C5+A5+B10+D80),waste cookedoil biodiesel 10% +algal biodiesel 10% + Butanol 15% + diesel 65% (C10+A10+B15+D65),waste cookedoil biodiesel 15% + algal biodiesel 15% + Butanol 20% + diesel 50% (C15+A15+B20+D50), waste cookedoil biodiesel 20% + algal biodiesel 20% + Butanol 25% + diesel 35% (C20+A20+B25+D35) in table 4.

On analyzing the performance of blended biodiesel in different compositions, observed that the performance of composition A2+B8+D90 is suitable for diesel fuel engineto replace the traditional diesel fuel and have a high load carrying capacity, highdefiance to rubber, packing (Dwivedi et. al., 2015) and A2+B8+D90fuel is heavier than water and high oxidation stability (Khana et al., 2016).

On complementary blending to increases the performance of diesel engine, waste cooked oil based biodiesel, algal biodiesel with butanol and diesel fuel, reported that the C2+A2+B8+D88is suitable for diesel fuel engine and replace to the conventional fuel (Shashi Chwala, 2004). The percentage of moisture content in C2+A2+B8+D88 is less than the other composition and the complete combustion of fuel and also the higher flash point of C2+A2+B8+D88but the saponification value of

C2+A2+B8+D88is quite high (Pinzi et al., 2009) and to be reduced in further work. On the basis of the above comparative study composition of blending C2+A2+B8+D88 were shows the ideal conditions for fuel and also observed that the percentage composition of blended waste cooked oil based biodiesel with butanol and diesel fuel engine is suitable for diesel fuel engine and replace to the conventional fuel. In the investigationalso shows that the oxidation stability of C2+A2+B8+D88 is higher as compared to that of the blending of A2+B8+D90and higher load carrying,Fuel with high specific gravity has high API with high ignition quality (Chen et al., 2010).

4. Conclusion

In the present study, biodiesel was synthesized from cooked oil and harvest algae and used to make blends by Inline blending method with butanol and conventional diesel fuel to analyze the performance characteristics. It can be concluded that, by Inline blending method among the tested blends C2+A2+B8+D88fuel was found to be a more suitable and sustainable blended fuel to replace the traditional diesel fuel. Furthermore the research work may be carried out to characterize the emission characteristics of the blended fuel.

Conflict of interest:

Authors declare that they have no conflict of interest.

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