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NOVEL APPROACHES FOR THE PRODUCTION OF BIO-DIESEL USING WASTE VEGETABLE OIL

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Abstract: At the present moment worldwide waning fossil fuel resources as well as the tendency for developing new renewable biofuels have shifted the interest of the society towards finding novel alternative fuel sources. Biofuels have been put forward as one of a range of alternatives with lower emissions and a higher degree of fuel security and gives potential opportunities for rural and regional communities. Biodiesel has a great potential as an alternative diesel fuel. In this work, biodiesel was prepared from waste cooking oil it was converted into biodiesel through single step transesterification. Methanol with Potassium hydroxide as a catalyst was used for the transesterification process. The biodiesel was characterized by its fuel properties including acid value, cloud and pour points, water content, sediments, oxidation stability, carbon residue, flash point, kinematic viscosity, density according to IS: 15607-05 standards. The viscosity of the waste cooking oil biodiesel was found to be 4.05 mm^2/sec at 40°C. Flash point was found to be 128°C, water and sediment was 236mg/kg, 0 % respectively, carbon residue was 0.017%, total acid value was 0.2 mgKOH/g, cloud point was 4°C and pour point was 12°C. The results showed that one step transesterification was better and resulted in higher yield and better fuel properties. The research demonstrated that biodiesel obtained under optimum conditions from waste cooking oil was of good quality and could be used as a diesel fuel.

Key Words: Biodiesel, Fuel, Transesterification, Viscosity, Waste cooking oil.

INTRODUCTION

During the 21st century transport fuels demand has grown dramatically throughout the world. Oil prices have risen radically year by year. The world continues to seek economically and environmentally sound alternatives to fossil fuel-based transportation fuels and power. India will become a diesel-deficit nation by 2016, as demand will far outstrip supply. Diesel demand in the country is growing at an annual rate of 8%. Biofuels have been put forward as one of a range of alternatives with lower emissions and a higher degree of fuel security and gives potential opportunities for rural and regional communities to benefit, as well as urban communities[1].

In 2010 worldwide biofuel production reached 105 billion liters (28 billion gallons US), up 17% from 2009 [2]. Biofuel is a type of fuel whose energy is derived from biological carbon fixation; worldwide biodiesel is the most common biofuel it is the variety of ester based oxygenated fuel. Biodiesel, as an alternative fuel, has many qualities. It is derived from a renewable, domestic resource, thereby relieving hope on petroleum fuel imports. It is biodegradable and non-toxic. Biodiesel has a more favorable combustion emission profile compared to petroleum-based diesel, produced low emissions of carbon monoxide, particulate matter and unburned hydrocarbons [3].

Rudolf Diesel hundred years ago tested vegetable oil as fuel for his engine. Recent years because of increases in crude oil prices, limited resources of fossil oil and environmental concerns there has been a renewed focus on vegetable oils to make biodiesel fuels [4]. Vegetable oil is divided to two main categories, edible oil and non-edible oil (*Jatropha Curcas, Pongamia Pinnata, Algae and Madhuca Indica plants*). Edible oil is oil which is use in food industry while non-edible oil is oil which is not use in food industry [5]. Edible oil can be divided into two main categories that are virgin oil and waste cooking oil. Virgin oil is oil a pure vegetable oil such as sunflower, palm, soy bean and rapeseed oil while waste cooking oil is vegetable oil from used frying oil collected from restaurants, catering, and hotel. Waste cooking oil can be the possible low cost feedstock for biodiesel production. The advantages of using waste cooking oil to produce biodiesel are the low cost and prevention of environment pollution. Due to the high cost of disposal, many individuals dispose waste cooking oil directly to the environment especially in rural area. Encinar *et al.*,[6] concludes that use of waste cooking oil is an effective way to reduce the cost of biodiesel production and significantly enhances the economic viability of biodiesel production.

Generally, there are four methods to produce biodiesel from vegetable oil and animal fats. There are direct use and blending, microemulsion, thermal cracking (pyrolysis) and transesterification [7]. The most commonly used method is transesterification. The main objective of this paper was to study the possibility of biodiesel production from Waste cooking oil through single step transesterification.

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MATERIALS AND METHODS

Materials

Waste cooking oil (WCO) was collected from a local hotel in Hyderabad, India. The WCO was used in frying foods. Potassium hydroxide flakes (KOH) and methanol GR (CH_3OH) were procured from Merck Specialties, Mumbai. Transesterification reaction was performed in a 1000 ml beaker and hot plate with magnetic stirrer arrangement was used for heating the mixture in the beaker. Separating funnel 1000 ml was used for transesterification reaction mixture separation.

Alkali catalyzed transesterification

In this study, an alkali catalyzed transesterification process was conducted to convert WCO into biodiesel. Collected WCO sample was allowed to stand for about 2-3 days so that impurities would settle down, then WCO was filtered to remove food residues and solid precipitate in the oil. The appearance of the WCO was clear, transparent, and in dark yellow in which some degradation products and water may be present. Before the alkali catalyzed transesterification, the WCO was heated to about 120°C for 60 min to remove the water and other volatile impurities as the pretreatment step because every molecule of water would destroy a molecule of catalyst. Potassium hydroxide was used as catalyst in this experiment. The amount of catalyst had an impact in the conversion of esters during the transesterification process. The titration was carried out in order to determine the optimum amount of catalyst concentration of for efficient transesterification. From the titration, the total amount of catalyst per liter of WCO was determined to be 8 grams of KOH per liter of WCO. The transesterification reaction was carried out using 100% technical grade ethyl alcohol. The alcohol used was 250 mL per liter of WCO. The premixed solution of methanol and catalyst (KOH) were added into the WCO in a beaker to carry out the transesterification reaction in stirred condition for another 60 min at 300 rpm and 45 °C, respectively. After the alkali-catalyzed transesterification treated WCO was transfer in a separation funnel and then reaction solution was left overnight to settle, a process that resulted in phase separation (Glycerol and Biodiesel). Once separate the glycerin from biodiesel in a separation funnel, all of the glycerol remained in the bottom phase, glycerol was carefully separated from the bottom of separation funnel which contained 81% glycerol, 8% water, 3% methanol and 9% Potassium hydroxide. The ester layer (biodiesel) was washed two to five times with water to remove any residual methanol, KOH, or glycerol that may be present. The mechanism of synthesis of biodiesel via single-step transesterification process is represented in figure 1.

Figure 1: experimental conditions for converting triglyceride to biodiesel (Transesterification)

RESULTS AND DISCUSSION

Biodiesels are characterized by their acid value, viscosity, density, cloud and pour points, flash point, carbon residue. According to the Indian and European standards biodiesel must meet some specifications as a fuel in the internal combustion engines. Therefore, some important properties for the produced biodiesel was measured and listed in Table 1.

Table 1: Fuel properties of the produced biodiesel

Parameters	Test Method	Standard Limit As per IS:15607-05	Result
Acid Value, mg KOH/g	IS:1448(P-1/Sec-1)	0.5 Max.	0.2
Pour Point	IS:1448(P-10)	----	12
Cloud Point	IS:1448(P-10)	----	4
Water Content, mg/kg	IS:1448(P-40)	500 Max.	236
Sediments,% by mass	IS:1448(P-30)	----	Nil
Oxidation Stability(at 110°C)hrs	EN-14112	6 Min.	8.3
Carbon Residue,% by mass	ASTM-D 4530	0.05 Max.	0.017
Flash Point,°C	IS:1448(P-21)	120 Min.	128
Kinemetic Viscosity at 40°C(cst)	IS:1448(P-25)	2.5-6.0	4.05
Density at 15°C kg/m3	IS:1448(P-32)	860-900	868

Waste cooking oil biodiesel properties

Acid value: The IS: 15607-05 standard for acid value for pure biodiesel is 0.5 mgKOH/g maximum. Lang et al, 2001 [8] reported that the acid values of the biodiesels of linseed oil, canola oil, sunflower oil and rapeseed oil were 0.88, 0.86, 0.87 and 0.87 mgKOH/g, respectively. The test result for the acid value for WCO fuel was found to be 0.2 mgKOH/g. The acid value is the total amount of potassium hydroxide necessary to neutralize the free acids in biodiesel sample. Higher acid value could also cause degradation of rubber parts in older engines resulting in filter clogging.

Cloud and Pour point: The key flow properties for winter fuel specification are cloud and pour point. Cloud point is the temperature at which a cloud of wax crystals first appear in the oil when it is cooled. The pour point is the lowest temperature at which the oil sample can still be moved. These properties are related to the use of biodiesel in the cold temperature. Biodiesel has a higher cloud point and pour point compared to conventional diesel[9]. There are no European or US specifications for low temperature properties (each country is free to determine its own limits according to local weather conditions), but it is well known that biodiesel fuels suffer from cold flow higher than mineral diesel fuel[10]. The cloud point and pour point of produced WCO fuel was found to be 4°C and 12°C. Lang et al,2001[8] reported the cloud and pour point of biodiesel of linseed oil, canola, sunflower and rapeseed oil were -2°C, -1°C, -1°C, -2°C and -6°C, -6°C, -5°C, -15°C respectively. The WCO fuel cloud point was approximately 4°C and pour point was approximately 15°C higher than those of the corresponding biodiesels. This indicates that the WCO fuel marginally gives bad perform in cold temperatures than the corresponding biodiesels.

Water content and sediments: Water and sediment contamination are basically housekeeping issues for biodiesel. Biodiesel can contain as much as 1500 ppm of dissolved water while diesel fuel usually only takes up about 50 ppm [11]. The standards for biodiesel (IS: 15607-05) limit the amount of water to 500 mg/kg maximum. In this experimentation found that there was no sediment content in the sample. We found that there was 236mg/kg water content in the sample this content below the IS standards. Water content of biodiesel reduces the heat of combustion. This means more smoke, harder starting, less power. Water will cause corrosion of vital fuel system components fuel pumps, injector pumps, fuel tubes, etc. Water is part of the respiration system of most microbes. Biodiesel is a great food for microbes and water is necessary for microbe respiration. The presence of water accelerates the growth of microbe colonies which can seriously plug up a fuel system [12].

Oxidation stability: Oxidation stability is an important quality standard for biodiesel. Transestrification of waste cooking oils with methanol produces the methyl esters of the fatty acids [13]. These have only a limited shelf-life as they are slowly oxidized by atmospheric oxygen. The Oxidation stability of the WCO biodiesel 8.3 was higher compared to 6 minimum (EN-14112) standards. Resulting oxidation products can cause damage to combustion engines [14]. R.L. McCormick et al, 2007[15] examined the factors impacting the stability of biodiesel samples collected as part of a 2004 nationwide fuel quality survey in the United States. They noticed that the oxidizability has the largest impact on both increasing insoluble formation and reducing induction time.

Carbon residue: Carbon residue is the amount of carbon residue left at the end of the fuel combustion process and is a measure of the extent of the complete combustion of the fuel [16]. The carbon residue of the WCO biodiesel 0.017% was lower compared to 0.050 max documented[17]. A greater amount of carbon residue indicates a greater extent of incomplete combustion or inferior burning of liquid fuel [18]. Our WCO biodiesel will form a lower Carbon residue deposits.

Flash point: Biodiesel has a high flash point compared to petroleum diesel fuel. Flash point can be used as a measure of the volatility of a fuel. Flash point value of the present WCO fuel was 128°C our value was higher than European, US and Indian specifications. European specifications require biodiesel fuels to have at least 101°C flash point, whereas in the US the minimum required level is lower (93°C) and Indian specifications required level is 120°C minimum [19]. U. Rashed and F. Anwar, 2008[20] reported in the literature higher the flash point, the safer is the fuel.

Kinematic viscosity: Viscosity is the most important property of biodiesels since it affects the operation of fuel injection equipment, particularly at low temperatures when an increase in viscosity affects the fluidity of the fuel. Vegetable oils can be used as fuel for combustion engines, but their viscosity is much higher than that of common diesel fuel and requires modifications to the engines. The major problem associated with the use of pure vegetable oils as fuels for diesel engines is high fuel viscosity in the compression ignition. High viscosity leads to poorer atomization of the fuel spray and less accurate operation of the fuel injectors. The lower the viscosity of the biodiesel, the easier it is to pump and atomize and achieve finer droplets. Thus, vegetable oils are converted into biodiesel by transesterification[21, 22]. Kinematic viscosity value of the produced sample range is 4.05. Our value was lower than some reported biodiesel fuels prepared from used cooking oil (4.77, 4.80 and 4.89 mm^2s-1) [19, 23, 24]. Indian specifications (IS:15607-05) state an acceptable biodiesel viscosity range between 2.5 and 6 mm^2/s which means that above mentioned WCO extreme limit should be in B100 form.

Density: Biodiesel quality determines by using property of density. Density is the weight of a unit volume of fluid. Fuel injection equipment operates on volume metering system, hence a higher density for biodiesel results in the delivery of a slightly greater mass of fuel this will affect the air-fuel ratio and there is a correlation between density and NOx emissions, with lower densities favoring lower emissions of NOx [25, 26]. The density of WCO biodiesel at 15°C was found to be 868 kg/m^3 which was in the range recommended by Indian standards. The Indian standard for biodiesel density is 860 kg/m^3 to 900 kg/m^3. Tate et al ,2006 [27] stated that density is a function of temperature and decreased linearly for canola methyl esters, soy methyl esters, and fish oil ethyl esters by 1.23 kg/m^3 °C for temperatures between 20–300°C.

CONCLUSION

The findings of this work clearly indicate that, Biodiesel production from waste cooking oil is feasible by alkali catalyzed transesterification with appropriated conditions. In the present study, spent waste cooking oil was chemically converted to biodiesel fuel via one step transesterification, using potassium hydroxide with methanol. The produced biodiesel is of good quality within the array of standard method specifications. The biodiesel was characterized for its fuel properties using IS: 15607-05 standard methods for biodiesel fuel quality assurance. From the tests, the viscosity of the waste cooking oil biodiesel was found to be 4.05 mm^2/sec at 40°C. Flash point was found to be 128°C, water and sediment was 236mg/kg, 0 % respectively, carbon residue was 0.017%, total acid value was 0.2 mg KOH/g, cloud point was 4°C and pour point was 12°C. Out of 10 properties tested, 7 of them met the IS: 15607-05 criteria for fuel standard. Biodiesel from used cooking oil could be used as a diesel fuel which considered as renewable energy and environmental recycling process from waste oil after frying and helps improve the biodiesel economics.

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