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Research Paper

Studies on Use of Waste-cooking Oil as a Diesel Substitute through Trans-esterification

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ABSTRACT

Biodiesels are substitute fuel sources that can be potential replacement to fossil fuels apart from being eco-friendly owing to their carbon-neutral nature. The energy originating from nature-based resources has a premium value due to its lowest environmental impact. The strategies that protect nature are grouped under a philosophy termed as 'sustainability'. The biodiesel ought to give net energy acquire, have ecological advantages with financially serious, and producible in enormous amounts without diminishing food supplies. The proposed study examines potential of waste cooking oil as a source of bio-diesels by collecting samples of used cooking oil from the food outlets. The characteristics of producing bio-diesel from waste cooking oil are investigated from the point of view of utilizing it on a small batch mode of 5 to 10 litre. The chemistry of transesterification is investigated by adopting computational route to design a reactor and experimentally verifying the small-scale production.

KEYWORDS: Biodiesel, Free Fatty Acid, Trans-esterification, Fuel properties.

Introduction and Relevance

The current situation of world fuel utilization is enormous and is ever expanding on account of the growing population that needs support for transportation and energy generation to meet daily needs. The concept of bio-diesel is included under the renewable energy source and hence a suitable contender to polluting fossil-based fuel that is drawn from underground resources. The fossil fuels are associated with disturbing degrees of contamination. The concept of plant-based oil has been in use for a long time, much earlier to conception of fossil fuels. The exploration of oil seeds or plant-based fuel sources have been less supported on account of priority fixed to food over transportation. In India we have an assortment of plant conceived non-palatable oil seeds species used in related stock chains of bio oils, particularly utilized as home-grown lighting from ancient times. There is likewise a past filled with bio oil utilized in motor generally in the rustic or horticulture area either on account of shortage of diesel or due to in availability of getting from distant regions.

The priority of conserving food value has been deterrent factor that prevented extensive usage of bio-diesel as fossil fuel substitutes. To satisfy the growing demand for fuel, the exploration of sources that are non-edible has been obvious choice as replacement to conventional fuels. The direct extracts obtained from plant sources in their natural forms do not always have a suitable burning cycle, hence need appropriate processing before being utilized for engine applications. Biodiesel is a liquid fuel obtained from complex unsaturated fats obtained from plant and animal sources. The fuel obtained from these nature-based sources through blended reaction with methanol yields biodiesel through the process referred as 'trans-esterification'. The by-products in this fuel transformation process include glycerine that gets isolated from utilized in the vegetable oil break-up. The methyl-ester gets separated during the process and extracted as 'biodiesel' apart from glycerine left over that forms a harmless material with minimal or nil impact on ecosystem on account of its usage as a degreasing material.

The large-scale production of Biodiesel can bring the price to affordable limits, but however the raw material for this process is dependent on the agricultural produce that has a food value. Therefore, biodiesel has not been a strong contender to fossil fuel, owing to lesser efforts to promote bio-diesel as an alternate to cheaper fossil fuels that are produced on mass scale. Therefore, biodiesel refers to a normal closed carbon cycle (approximately 78%), as it is found in endless biomass sources, against fossil fuel based petro-diesel. The bio-diesel is associated with lower toxicity as it is drawn from carbon-neutral photosynthetic process and it improves motor performance when used along with fossil fuels. The Bio-Diesel blend refers to combination of biodiesel and diesel based on high-quality hydrocarbon. The strategy of mixing bio-diesel with fossil-fuels helps conserve the high energy fossil fuel and also reduces the environmental impact of consuming fuel. A mix of up to 20% biodiesel has been reported to be feasible from technical and economic perspectives. However, for complete substitution of diesel by biodiesel requires engine modifications that may not be economically favourable. The use of blended fuels in existing engines can likewise be utilized similarly in its non-destructive detailing (B100). Two-fold cutting of mustard can make for an extraordinary oil collect and assists with transforming the yield into grains, and partake in the additional advantage of having an additional feast after the oil has scattered can go maybe as a functioning and breaking down pesticide. The oil extracted from seeds depends upon nature of the agricultural produce on account of the composition of fatty acids. The percentage of tri-glyceride in the feed-stock decides the quantum of the end produce obtained in the oil-extraction process. The pure vegetable or animal extracts cannot be directly utilized as an engine fuel, hence it needs suitable reformation through process termed as 'trans-esterification'. The use of suitable feedstock hence becomes vital in making Bio-diesel production economically and technically feasible. The important requirements of the fuel include the calorific value, emission characteristics, viscosity, flash and fire point.

Literature Review

The brief overview on research linked to engine operation on biodiesel fuel is presented here.

Reddy N.V., et al., (2013) reported on non-toxic nature of bio-diesel and its potential as an engine fuel presenting case studies of rough rice, wheat oil and rice grain oil [1]. Umesh et al., (2014) highlighted biodiesel production and its utilization in IC engines [2]. Singh J et al., (2015) claimed HC, CO and NO_X reduction with no major engine modifications in engine hardware [3].

Shah P. R. et al., (2015) reported B100 blend of rice grain biodiesel lead gave higher smoke, HC and NO_X in contrast to diesel fuel [4]. Subhan Kumar Mohanty et al., (2013) have reported calorific value of biodiesel to be 7% lower than diesel [5]. Bobade S. N. et al., (2012), reported on transesterification of Karanja oil gave 907 ml of Karanja oil biodiesel and 109 ml of glycerol utilizing 13% of methanol and 1% of impetus [6]. Prasada R et al., (2014), reported on Pongamia pinnata biodiesel blended with diesel fuel [7]. Baste S. V. et al., (2013) reported that biodiesel produced from sustainable feed-stoke was non poisonous and biodegradable [8]. Halder et al., (2014), stated Bangladesh had 0.52 MT of biodiesel to minimize its diesel import by 21.67% [9]. Heroor S. H. et al., (2013) reported 10% oxygenated biodiesel assist better combustion [10]. Huang D., et al., (2012) assessed oil to supply 80% of world's energy [11]. Ncibi M. C. et al., (2013) investigated available bio-resources and/or wastes to produce biodiesel [12]. Harsha Vardhan et al., (2019) reported highest yield for cotton seed methyl ester, at 6:1 methanol/oil molar ratio and 1 wt% of NaOH catalyst [13]. S. T. Aly et al., (2019) used methanol to oil molar ratio of 6:1 for trans-esterification [14]. Praveen Kumar. M. R et al., (2019) used non-edible oils like cottonseed, jatropa and Mahua oils in transesterification [15]. Kulkarni A. M. et al., (2019) reported bio-diesel blends to help control air pollution [16]. Dwivedi G. et al., (2013) reported up to B20 blends no engine alteration was needed [17] Karmee S K et al., (2015) reported use of waste cooking oil as biodiesel source [18]. Aladetuyi A et al., (2014), reported on trans-esterification of cocoa case garbage [19]. Aasif Khan A et al., (2015) reported on dwindling petroleum resources and role biodiesel [20]. A. Ganesh et al., (2015), highlighted emission aspects of Bio-diesel against fossil fuels [21]. Babu R. et al., (2015) reported on Niger seed as a potential biodiesel source found in Ethiopia, India, Myanmar and Nepal [22].

Demirbas A. et al., (2008) used Chlorella protothecoides and Cladophora fracta algae for oil [23]. Yaakob Z. et al., (2013) assessed economic aspects of biodiesel [24]. Yong wang et al., (2006, 2007), reported on conversion of free WCO oil to biodiesel [25, 26]. Gashaw A. et al., (2014), reported on biodiesel as diesel alternative [27]. Sheinbaum C. et al., (2013), examined the possible use of biodiesel fuels produced by wasteful cooking oil (WCO) in Mexico and its CO_2 emissions reducing the potential of Mexican cars and related costs. The results show, in light of the 2010 data, that biodiesel emissions from WCO between 7.8 PJ and 17.7 PJ are limited to 1.5% and 3.3% of petrol-diesel consumption in the road transport area and may be reduced elsewhere. somewhere in the range of 0.51 and 1.02 Mt of CO_2, (1.0% -2.7% of CO_2 related emissions), depends on WCO's recovery rate in the use of vegetable oil in cooking and assuming CO_2 emissions for biodiesel production and timely methanol emissions of creation and stitching in the mix [28]. Hingu S et al., (2010), reported on use of sonochemical reactors with a biodiesel compound in waste cooking oil. Transesterification was used sweetened oil containing methanol, within potassium hydroxide as a stimulant tested using a low reactor ultrasonic reactor (20 kHz). The effect of various operating parameters, for example, alcohol ratio, concentration, temperature, strength, heat rate and horn position at oil conversion rate was assessed. [29]. Kannan G.R. et al., (2012) adopted Response Surface Methodology in bio-diesel studies [30].

The literature review on biodiesel from different oil gave an insight about how the biodiesel can be a game changer for the world. It also shows that the different potential oil seeds for biodiesel production can be subjected to trans-esterification.

Design and Working of Biodiesel Plant

The process of trans-esterification was performed using a experimental set-up as indicated in Fig. 1 following the prescribed procedure in the literature survey. It consists of a tank with 5-6 litre capacity of waste cooking oil (WCO) to support its heating up to a temperature of 60ºC. The heat supply is regulated by use of thermostat set to prescribed temperature limit. The heating process is followed by adding methanol and NaOH (catalyst) to the heated oil sample in the tank. The proper mixing of all the constituents was ensured by continuous stirring for about 2 hours approximately, using a pump or stirrer move the oil. After that use the condenser so that the methanol does not get evaporated. The mixture is kept for a day so that it gets settled and a after a day there are 2 layers formed, bottom layer is a layer of glycerol which is in a raw form and we can use it for soap and other detergent products.

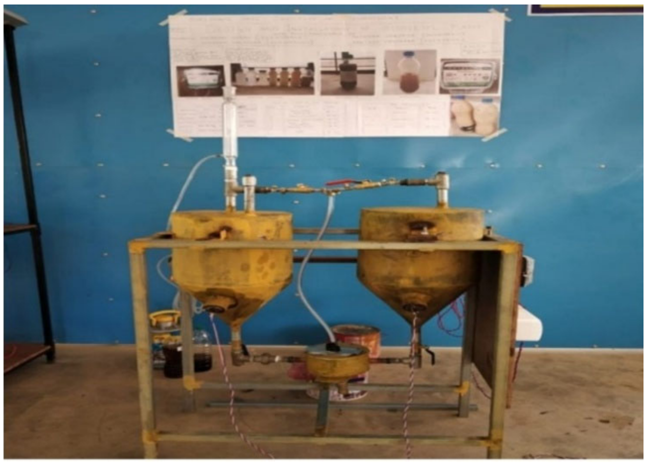


Fig. 1. Biodiesel plant

After the separation of glycerol, start the pump so that the oil flows into the next tank for the next process. Evaporation process now starts as purified water is used for cleaning the oil and to remove the impurities and methanol. Heat the water for 50-60 degrees Celsius continuously. After continuous washing the oil, collect the impure water which gets collected at the bottom; wash it properly till we get the cleaning water as clean as the water. After getting clean water as the output drain all the oil from the tank

Computational Studies on Bio-Diesel Preparation

The use of computational tool offers advantages of minimizing the design cycle in terms of cost as well as the associated time for evolving the final design. The study is based on use of 3D CAD, parametric element (based on history) and powerful new display systems. The initial conceptualization of the equipment was based on use of Solid-Edge tool as illustrated in Fig. 2 that provides step-by-step execution of the computational methodology is developing the trans-esterification device. The detailed step by step procedure for Solid edge Software is given in the flowchart represented as Figure 3.3 designed with Solid-edge tool

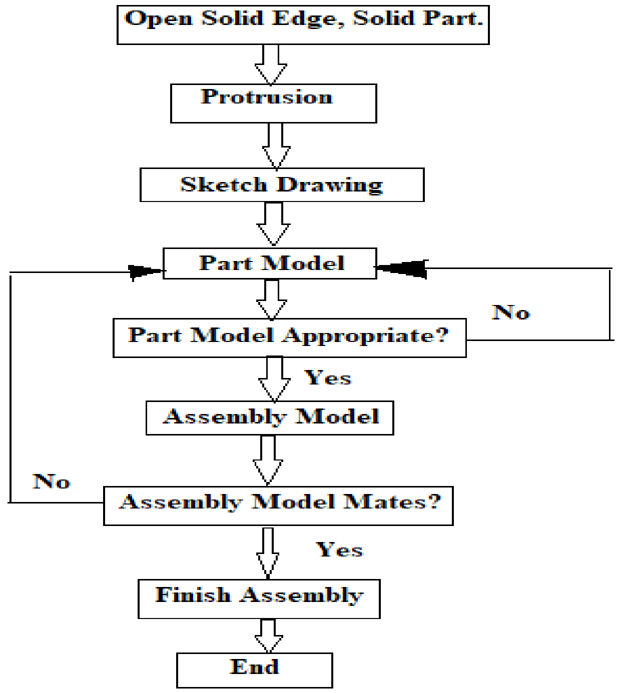


Fig. 2. Flowchart of computational work

The steps involved in execution of the modeling includes the use of several draft commands like protrusion, geometry definition, Material choice, cut-out to remove excess material, Assembly, and Relationship types to connect the two different parts

Experimental Studies on Bio-Diesel Preparation

The process of Biodiesel preparation uses different equipment as discussed in the previous section. This section highlights the various components used in building a system that helps prepare the bio-diesel

1. **Equipment used in the study:** This experimental set-up used for preparation of biodiesel from WCO consists of different components as presented in Fig 3 and Fig 4.

(a) Pump (b) Heater

Fig. 3. Heat and circulation equipment for the trans-esterification

The circulation device has a capacity of 12 LPM operating at 850 RPM. A siphon is a fluid-carrying gadget (liquids or gases), or often slurries, for mechanized work. Siphons can be ordered in three important circles as indicated by the strategy they use to deliver fluids: direct lifting, extraction and removal of communities. Siphons work with a specific system and heatup to perform the function of a fluid-carrying machine. Siphons work with a wide range of fuel sources, including manual, power, motors, or wind power, coming in a wide range of sizes, from the moment of use in clinical applications to large-scale siphons.

Electric heating was used to provide the necessary heat input to the chemical reaction of transforming waste cooking oil into bio-diesel through the process of trans-esterification. Electric heater converts flow of electricity into heat. Many current electric heating gadgets use nichrome wire as a powerful component; the heating element, shown on the right, uses a nichrome wire retained by ceramic inserts. The advice is that these can go to high temperatures and cause painful burns. It uses power around 220V-240V, 60Hz, 500W.

(a) Condenser

(b) Thermometer

(c) Energy-meter

Fig. 4. Condenser and measuring equipment for trans-esterification

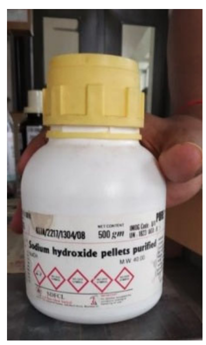
In framework including heat removal device termed as Condenser. It is a gadget or unit used to gather a substance from its vaporous to its fluid state, by cooling it. In this manner, the inert warmth is surrendered by the substance and moved to the general climate. Electrical appliances use electricity meters installed on client premises for charging purposes.They are usually adjusted to the charging units, commonly known as the kilowatt hour (kWh). They are usually used once each charge. At times when energy savings are demanded, a few meters may measure the application, excessive use of energy at other times.

A thermometer was used to measure the temperature of the reacting medium at various instances of the trans-esterification process.

2. **Material used in the study:** The trans-esterification is a chemical reaction to convert the waste cooking oil into a more refined fuel termed as 'bio-diesel'. The major participating material in this chemical reaction included the feed-stock, base in form of Methanol, Catalyst in form of sodium hydro-oxide. This section gives a brief account on these material used in preparation of bio-diesel from the waste cooking oil that was mainly procured from the eating food outlets in Karwar location.

(a) WCO

(b) Methanol



(c) NaOH

Fig. 5. Material used during the preparation of Waste cooking oil bio-diesel

The fig 5 shows the WCO used to produce the biodiesel. This oil can be easily got from the hotels, restaurants and home. When we collect the waste cooking oil from hotels it contains dust particles and small impurities which need to be filtered. Vegetable oil reusing is progressively being completed to deliver a vegetable oil fuel.

NaOH is an exceptionally scathing salt that disintegrates proteins at standard encompassing temperature and may cause extreme substance consumes. It is exceptionally dissolvable retains dampness and carbon dioxide from air.

3. **Experimental set-up for trans-esterification:** The fig 6 shows the tank used in the plant to store the oil. It is a storage where the oil is store and all the processes are carried out. The tank has the capacity of 10 litres.

(a) Reactor Tank

(b) Flow control value

Fig. 6. Process control Equipment used

It is a storage device where the oil is stored and all the processes has been carried out such as heating of oil (waste cooking oil after the trans esterification process) at a temperature of 60 degree Celsius. The tank has the capacity of 10 litres and it is made up of m.i. steel (mild steel which has carbon content of less than 0.25%). This tank is also used for washing of row bio diesel by using the water, after which we get the pure form of bio diesel.
The fig 6 (b) shows the valve used in the Biodiesel plant which is used to control, directs the flow of biodiesel in the plant.

Results and Discussion

This section deals with the results related to Fuel properties of biodiesel produced from wastecooking oil, Biodiesel Plant load factor calculations, software computations related to study

The Table 1 shows the comparison of fuel properties of normal cooking oil, Diesel, and Biodiesel produced from waste cooking oil which are obtained during the properties test of Biodiesel. The most important properties of fuels are properties such as viscosity, surface tension, Flash point, Fire point, ignition tendency, Density and calorific value. Some of whichare discussed below.

TABLE 1

Fuel properties

Properties	Oil	Diesel	Biodiesel
Flash point in ˚c	327	52-66	165
Fire point in ˚c	330-360	62-110	180
Viscosity in mm^2/sec	0.8	2.5-3.2	4.5
Density in kg/m^3	910-930	832	875
Calorific value in MJ/kg	42	42-46	(37.27)

The calculations of free fatty acid shows the amount of NaOH we have to add in the waste cooking oil to reduce the viscosity of oil and to form a biodiesel, In this part we also calculate the density of biodiesel, kinematic and dynamic viscosity of the biodiesel produced.

1. **Determination of % of FFA value**

$$\% \text{ of FFA} = \frac{28.2 \times \text{burette reading} \times \text{Normality of NaOH solution}}{\text{Volume of oil taken}}$$

$$= \frac{28.2 \times 3.5 \times 0.1}{10} = 0.987 \qquad \text{.....(1)}$$

2. **Determination of catalyst of reaction, NaOH:** For FFA between 0 -0.5: Catalyst is 3.5 g/ litre; For FFA 0.51 – 1.0 4.5 g/ litre

   The catalyst used was 4.5 g/ litre of feedstock oil

3. **Weight of NaOH for solution**

$$W = \frac{NEV}{1000} \qquad \text{.....(2)}$$

   N = Normality; E = Eq. Weight of NaOH = 40; V = Volume of oil in test tube

$$W = \frac{0.1 \times 40 \times 100}{1000} = 0.4$$

4. **Kinematic viscosity**

$$\text{Viscosity} = (At - B/t)\ mm^2/sec \qquad \text{.....(3)}$$
$$= 4.5 mm^2/sec = 4.5 \times 10^{-6}\ m^2/sec$$

   Where A and B are constant

   A = 0.264, B = 190 when t = 40 to 85 seconds.

   A = 0.247, B = 65 when t = 85 to 2000 seconds.

5. **Fuel Density**

$$\text{Density} = (W_2 - W_1)/60 \times 1000\ kg/m^3 \qquad \text{.....(4)}$$
$$= 875.25\ kg/m^3$$

6. **Absolute or Dynamic Viscosity**

Dynamic Viscosity = Kinematic viscosity × density N-s/m^2

$$= 0.003937 \text{ N-s/m}^2 \quad \text{.....(5)}$$

Conclusions

The following are the conclusions drawn from the study

1. In the event of this project one can easily understand the importance of biodiesel as an alternative fuel. In today's world, software tool plays a very important role in this digital world so with the help of software tools, we can design the models and fetch the readings in a minute time and time is consumed.
2. The studies on samples of bio-diesel indicated that trans-esterification produced a free fatty acid FFA of about 0.987. The process require 22.5gms of NaOH and 1.5 litres of methanol to produce higher yield of bio-diesel in the order of 75% of biodiesel (3.5 litres from 5 litres of waste cooking oil).
3. The additional by products of commercial value obtained from the process included glycerine and phenol which can be used for making soaps and in floor cleaning.
4. The Bio-diesel obtained in the process had congenial fluid properties that include kinematic viscosity of 4.5 mm^2/sec, flash point of 165°C, fire point of 180°C and densityof 875 kg/m^3.

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