

Characterization Of Biodiesel Samples produced from Fresh and Waste Vegetable Oils to evaluate their Feasibility for Power Generation

Mehwish Inam*, Ayesha Mohy-ud-Din, Abdul Aziz Bhatti, Mashood Nasir.

University of Management and Technology, C-II, Johar Town, Lahore 54770, Pakistan.

Abstract— The purpose of this paper is to design a system in which the biodiesel prepared from fresh and waste vegetable oil can be converted into useful power output. It is intended that this biodiesel produced may ultimately be a fuel source for the power generation from the generators. The optimal conditions of temperatures and concentration have also been discussed and the criteria to select these parameters have been evaluated.

Keywords-biodiesel; transesterification; engine; brake specific fuel consumption; speed

I. INTRODUCTION

The increasing energy demand, prices of petroleum products and the environmental concerns resulting from the burning of fossil fuels in electricity production has resulted in focusing on the use of environmental friendly renewable alternative energy resources, like solar, hydro, tidal, wind, geothermal and biomass energy [1] & [2]. However there are some drawbacks of using these renewable energy resources. The total power generated by wind and tidal energy is confined and equipments to convert solar, wind and tide energy are expensive. Use of hydro power is already known to change the pattern of sedimentation in rivers. Geothermal energy produces heat along with poisonous gases. Biofuels has fewer disadvantages as compared to other renewable energy resources. The only drawback associated with bioenergy is that some waste materials are not available all year round. Thus biofuels appear to be the best solution to substitute fossil fuels.

Resources for bioenergy will not run out, they are becoming cost wise competitive with fossil fuels, they appear to be more environmental friendly and they are rather accessible to distribute and use as applicable infrastructure and technologies exists and are readily available. Nowadays, among biomass energy sources, biodiesel has gained much attention as an alternative fuel for diesel engines due to number of environmental characteristics such as low greenhouse emissions and pollution [3]. Various types of raw materials are available for the biodiesel production, such as virgin oils, waste vegetable oils and animal fats. Main advantage of this fuel is that the raw materials are natural, renewable, biodegradable and nontoxic [4]. Characteristics of the biodiesel may change with the oil source and the type

of alcohol used for its production [5]. Biodiesel is reported to have good lubricating properties which improves engine life and reduces engine component wear [6] & [7].

This paper aims the formulation and production of an efficient biodiesel that leads to replacement of conventionally used diesel with more energy contents at quite a reasonable cost.

II. MATERIALS AND METHODS

A. Chemicals and Standards

Sodium Hydroxide (NaOH), Methanol (CH₃OH), Hydrochloric acid (HCl), potassium hydroxide (KOH), Phenolphthalein indicator solution, Ethyl alcohol (CH₃COOH) were of analytical grade. Acetic Acid was of analytical grade and purchased.

B. Preparation of Biodiesel

The filtered oil was taken in the container and heated to 120°C for 5 minutes to evaporate any moisture present in the oil. 5.25 grams of sodium hydroxide (NaOH) were added to 0.16 litres of methanol and the mixture was stirred for 20 minutes by placing a magnet bar. The mixture of methanol and sodium hydroxide was stirred with oil for 90 minutes maintaining the temperature at 60°C. The mixture was allowed to settle for the whole night. As glycerine is heavier than the biodiesel, it would settle at the bottom. The glycerine was separated from the biodiesel by separating funnel. One millilitre of acetic acid (CH₃COOH) was added to washing water. This water was added to the oil washed for 12 hours and the water was drained off later. In second washing, the oil mixed with water was shaken in tilted position for 30 seconds and water was discharged by keeping the mixture in inverted position for to 6-8 hours. The phase of third washing included the light shaking of oil water mixture for one minute and kept again for 6-8 hours. In fourth phase of washing, mixture was shaken well in tilted position for one minute and water was discarded by putting the mixture inverted for 24 hours.

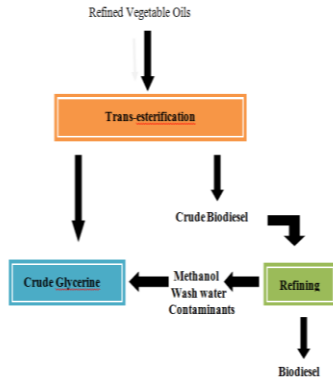


Figure 1. Schematic Diagram of Biodiesel Preparation

C. Assessing Biodiesel in Generator

Fresh and waste oil biodiesel and shell diesel were used for running the generator. Experimental setup was organized to calculate fuel consumption per unit time and the overall efficiency of the i.e. brake thermal efficiency. The amount of fuel consumed in an hour by the generator was determined by using diesel fuel consumption chart. The total electrical power load (brake power) consumed during an hour was measured by referencing the electrical output label on the generator. This could also be done by (Eq 2).The power equivalent of fuel is:

$$P_F = m_f * C_v \quad (1)$$

Where

fuel consumption rate in grams per second

LHV is the lower heating value of the fuel

In MEP [kPa], this becomes:

$$Fuel\ MEP = 2000 * \frac{P_F}{VN} \quad (2)$$

where V is the engine displacement in liters

N is the engine speed (rps)

The output of the generator in kWh was divided by the input value of the fuel (power of fuel) used in kWh. Multiply this figure by 100 to express it as a percent.

$$\eta = \frac{E_{in}}{E_o} \quad (3)$$

Where,

η =Energy Efficiency

E_{in} = energy input in KWh

The output of the generator could also be determines by the formula of brake thermal efficiency.

III. RESULTS AND DISCUSSIONS

A. Effect of Methanol Concentration

Alcohol to oil ratio is an important factor that affects the biodiesel yield and purity [8] &[9].Ester yield was maximum at a methanol concentration of 200 ml as in “Fig. 2”. For large amount of methanol, the separation of ester layer from water layer became more difficult. Due to the fact that methanol behaves as an emulsifier, longer time was observed for this separation.

B. Effect of Reaction Temperature

Experimental results depicted that the transesterification reaction could occur within the temperature range in preparation but the reaction time to achieve the reaction varied considerably with reaction temperatures. “Fig. 3” shows the effect of reaction time on yield of biodiesel production. It can be deduced from the figure that a high product yield could be obtained at 60°C and product yield started to decreases if the temperature exceeds 60°C. The reason for this is the acceleration of saponification side reaction of triglycerides at higher temperature.

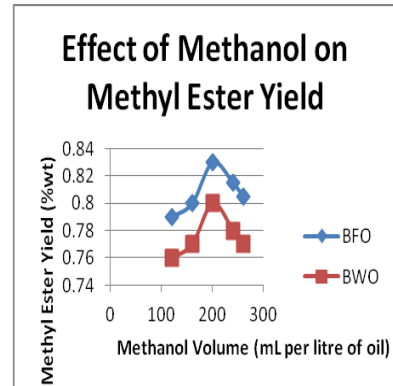


Figure 2. Effect of methanol concentration on methyl ester yield

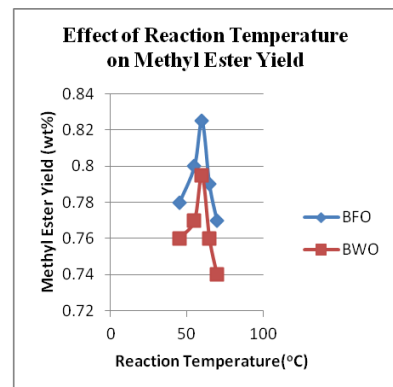


Figure 3. Effect of reaction temperature on methyl ester yield

C. Percentage Yield

Biodiesel is the product of the process of transesterification. After the mixture was cooled down, crude biodiesel and glycerin phases was be seen within few minutes. However, the crude biodiesel was cloudy and opaque. The clear separation was observed after 12-24 hours of settling. Washing of final ester products is a very important activity during biodiesel processing. The ester was washed several times with water. In this experiment, it was found that there was no water and sediment content in the sample. An electric heater was used to drive off the water and any remaining alcohol. The ASTM standard limit for water and sediment was is 0.05% by volume of the sample.

Percent yield is used is cases where a chemical transformation occurs. Percentage yield for biodiesel made from fresh oil (BFO) is calculated by the formula

$$\text{PercentageYield} = \frac{\text{VolumeofBFO}}{\text{VolumeofFO}} \quad (4)$$

$$\%Yield = (4 \text{ L} \div 5\text{L}) \times 100 = 80\%$$

Percentage yield for biodiesel made from fresh oil (FO) is calculated by the formula

$$\text{PercentageYield} = \frac{\text{VolumeofBWO}}{\text{VolumeofWO}} \quad (5)$$

$$\%Yield = (3 \text{ L} \div 5\text{L}) \times 100=60\%$$

D. Physical Test Results of BFO and BWO

The synthesized BFO,BWO and fossil diesel(Shell) used in UMT were characterized for their fuel properties (i.e.,density, kinematic viscosity, cloud point, pour point, flash point, and acid number)employing American Society for Testing and Materials (ASTM) methods. The results are given in Table 1.

TABLE 1

PHYSICOCHEMICAL PROPERTIES OF BIODIESEL SAMPLES AND SHELL DIESEL

Properties	BFO	BWO	Shell Diesel
Density (25°C,g/ml)	0.76	0.878	0.881
Kinematic viscosity (25°C,cSt)	5.94	6.78	6.3
Flash point (°C)	86	180	74
Acid number (mg KOH g ⁻¹)	0.74	0.37	0.12
Saponification value (mg KOH g ⁻¹)	55.36	92	25.5
Ester value	54.62	96.6	96.5
Cetane number	50.31	59.42	43.21

The saponification value of BFO was 55.36 that lies in the standard range but values of BWO and Shell Diesel were 92 and 25.5 that deviated from standard range to some extent. In our study, acid value for methyl ester of fresh canola oil was found to be 0.74 mg KOH/g but for fried canola oil it was relatively much lower (0.37 mg KOH/g). This can be improved by controlling the transesterification, cleaning and drying processes. To use biodiesel as fuel for IC engines, the highest limit of ester value should be around 85 as per standards. The ester value of BFO met the standard specification but BWO was not according to standard. Cetane number of BFO was 50.31 and that of BWO was 59.41 which showed them to be a good quality fuel as compared to shell diesel (cetane number: 43.21).

E. Engine Performance

a) Comparison of fuel efficiency: Fuel consumption is an important parameter for measuring fuel efficiency Specific

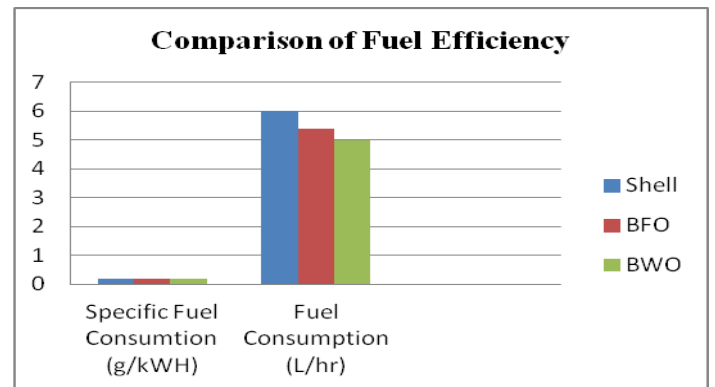


Figure 4. Comparison of fuel efficiency

fuel usage and annual fuel consumption were estimated for biodiesel under study and compared with diesel.

“Fig. 4” shows the specific fuel consumption and fuel consumption for BFO and BWO. The specific fuel consumption of BFO and BWO under study was similar to shell diesel. Fuel Consumption of Shell diesel was 6L/hr at full load, higher than BFO and BWO.

b) *Effect of load on brake specific fuel consumption* :It is an important parameter to analyse the performance of the engine and fuel efficiency. The effect of load on BSFC for BFO and BWO compared to diesel fuel is shown in Figure 5. The BSFC values of the three samples resemble closely but that of BWO was lowest because of its low calorific value and, hence, less fuel is needed for the same power output. The BSFC values were 0.19, 0.18 and 0.200 kg/kWh for BFO, BWO and shell diesel respectively at 100% of rated load.

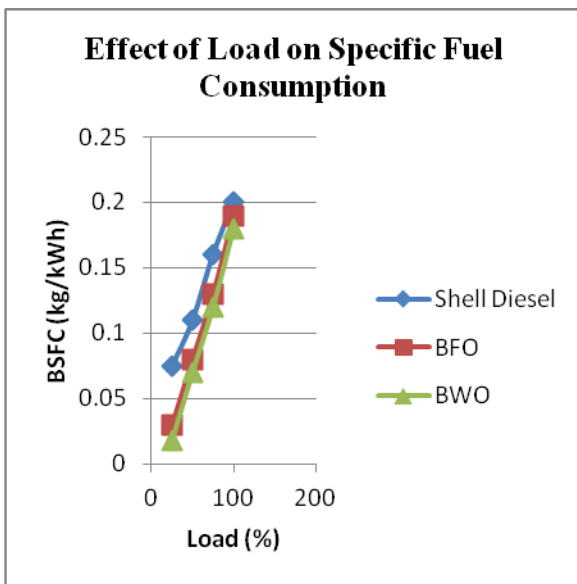


Figure 5. Effect of load on specific fuel consumption

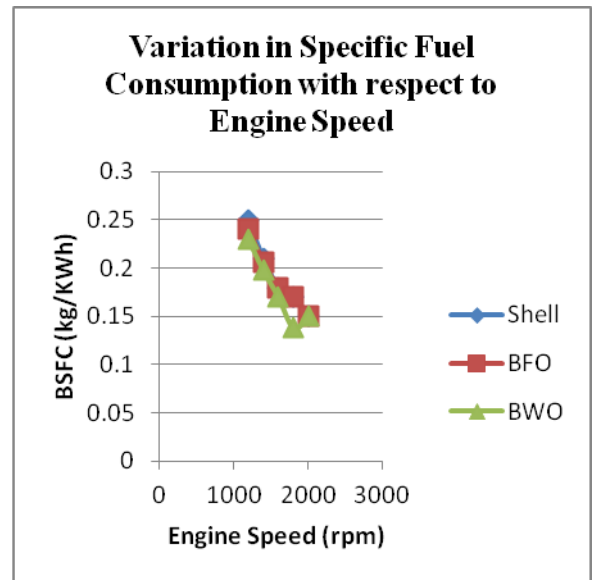


Figure 6. Variation in specific fuel consumption with respect to engine speed

c) *Variation in specific fuel consumption with respect to engine speed*: In Figure 6, BSFCs of BFO and raw BWO are compared to shell diesel. While minimum BSFC with BFO and diesel fuel is obtained at 2000 rpm engine speed, it is obtained. The BSFC of all three fuels have resulted in almost overlapped curves. Using BFO and BWO methyl esters, an average increase of 13% and 14% was obtained with respect to Shell diesel. In the literature, increases in specific fuel consumption with the use of methyl ester have been reported. By using cottonseed methyl ester, [10]observed an increase within the interval of 8–10% in specific fuel consumption with respect to diesel fuel.

d) *Comparative efficiency analysis*: The value of overall efficiencies of electricity generator working on sample of biodiesel with shell diesel is presented in Table 2. The overall efficiency of the 27.5 kVA electricity generator at full load fueled with samples of diesel was found in the range of 41-43% respectively as shown in “Fig. 7”. In the case of BFO produced more power, and overall efficiency was found at maximum than diesel-fueled generator due to complete combustion and reduction in calorific value of the fuel. In case of BWO, the operational efficiency was found less than the diesel-fueled condition.

During experimentation, it was observed that the engine ran very smoothly, without any noise and knocking when fueled with BFO. The engine was also run at constant revolution per minute in all the fuel samples.

TABLE 2.

EFFICIENCY OF ELECTRICITY GENERATOR RUNNING ON DIFFERENT FUELS

Sr.No	Fuel Sample	Calorific Value(kJ/g)	Fuel Energy Input (Pf=LHVxFR) kWh	Energy Output (kWh)	Overall Efficiency
1	BFO	43,400	29.74	12.8614	43.25%
2	BWO	39,300	19.73	8.16	41.34%
3	Shell Diesel	45,000	27.21	9.8	36.00%

CONCLUSIONS

Biodiesel was developed from fresh and waste oil by using alkali catalyzed transesterification process. The methanol concentration and temperature for the good yield of biodiesel were optimized to be 200 ml and 60°C. The fuel properties of biodiesel samples, such as kinematic viscosity, specific gravity, calorific value, and flash point, were found within the limit of ASTM standard. Overall physicochemical analysis showed that BFO is a better quality fuel as compare to BWO. The performance tests were conducted with petroleum diesel and biodiesel samples at different loads and variable speeds. On comparing the electrical efficiency of generator and BSFC values, it was observed that less fuel is required for same power output when BFO and BWO were used in place of petroleum diesel. Moreover, an increase in BSFC values of BFO and BWO as compare to petroleum diesel at different speeds leads to the same interpretation. Higher efficiency and lower BSFC values of BFO and BWO due to complete combustion and reduction in calorific value of the fuel. In case of BWO, the operational efficiency was found less than the diesel-fueled condition. Thus, biodiesel prepared from fresh as well as waste vegetable oil can be used as an alternate and nonconventional fuel to run diesel engine.

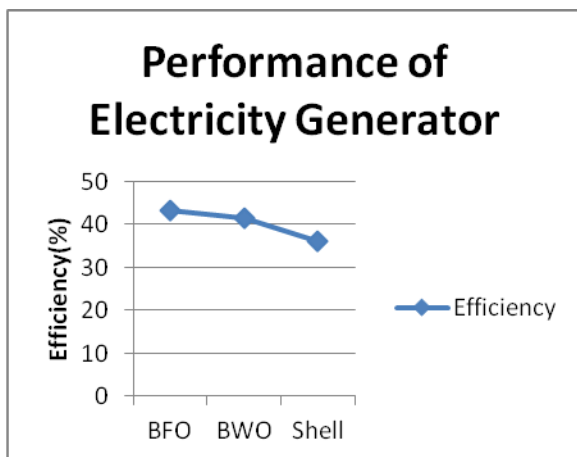


Figure 7 Performance of Electricity Generator

REFERENCES

- [1] M. Lapuerta, J.Rodríguez-Fernandez, and J.R.Agudelo, "Diesel particulate emissions from used cooking oil biodiesel," *Biores. Technol.*, vol.99, no.4, pp. 731–740, March 2008.
- [2] G.Tashtoush, M.I.Al-Widyan, and A.O. Al-Shyoukh, "Combustion performance and emissions of ethyl ester of a waste vegetable oil in a water-cooled furnace," *Appl. Thermal Eng.*, vol 23, no.3, pp.285–293, February 2003.

- [3] M.A. Dube, A.Y. Tremblay, and J. Liu, "Biodiesel production using a membrane reactor," *Biores. Technol.*, vol.98, no.3, pp. 639–647, February 2007.
- [4] J.M. Marchetti, V.U.Miguel, A.F. Errazu, "Possible methods for biodiesel production," *Renewable and Sustainable Energy Reviews.*, vol. 11, no.6, pp.1300-1311, August 2007.
- [5] F.Aksoy, "Analyzing the effects of methyl esters produced from raw soybean and waste frying oil on engine performance and NOx emission," *Energy Sources, Part A.*, vol. 34, no.2, pp.143-151, December 2011.
- [6] A.K. Agarwal, B. Jayashree, and L.M. Das, "Effect of biodiesel utilization on wear of vital parts in compression ignition engine," *J. Eng. Gas. Turbine Power.*, vol. 125, no.2, pp. 604–611,2003.
- [7] S. Sinha, A.K. Agarwal, and S. Garg, "Biodiesel development from rice bran oil: Transesterification process optimization and fuel characterization," *Energy Convers. Manage.* vol.49, no. 5 , pp.1248–1257,May 2008.
- [8] D. Y. C. Leung, and Y. Guo, "Transesterification of neat and used frying oil: Optimization for biodiesel production", *Fuel Proc. Technol.* vol. 87, pp.883–890, 2006.
- [9] B.Freedman, E.H. Pryde, and T.L. Mounts, "Variables affecting the yield of fatty esters from transesterified vegetable oils", *JAACS* vol.61, pp. 1638–1643, 1984.
- [10] H. S. Yücesu, and C. İlkılıç, "Effect of cotton seed oil methyl ester on the performance and exhaust emission of a diesel engine", *Energy Sources, Part A* vol.28, pp.389–398, 2006.