Impact of Alternative Fuels on Socio Economic Concern: Experiments, Experiences and Inferences

S. S. Bhusnoor[1], S. R. Nikam[2] and A.S. Saraf[3]

[1,2,3]*Department of Mechanical Engineering, K J Somaiya College of Engineering, Vidyavihar, Mumbai – 400077*
[1]siddappabhusnoor@somaiya.edu (corresponding author)

Abstract:
Climate change represents a serious threat to public health, environment, economic prosperity, and national security. It is necessary to increase public awareness related to causes of climate change and its adverse effects. Hence there is a need to enhance research, develop and promote green technologies, and prepare current students to become future environmental leaders. The focus of this study is to provide awareness of climate change and promote environment and health protection through the development of a biodiesel production facility and use of biodiesel in automotive vehicles to the undergraduate students. This hands on training (Biodiesel Production and its utilization), to the students has increased their interest in learning the course and same is reflected in their results and this activity also helped in attaining wide range of Programme outcomes at different levels**.**

Keywords: Biodiesel, Transesterification, Program outcomes, learning interest, Fuel Economy and Health effect

1. Introduction:
Alternative fuels, Energy Conservation and Management, Energy Efficiency and Environmental Protection have become important in recent years because of fossil fuel depletion and environmental degradation. Hence to overcome the fossil fuel depletion issue and from the environmental point of view, it is important to promote use of alternative fuels. From the literature it was found that crude oil can be used as a fuel for Internal Combustion (IC) Engines (Ramadhas and Muraleedharan, 2004).The major difficulties in using the crude vegetable oils in diesel engines are because of their high viscosity, low volatility and poor cold flow conditions (Bhusnoor, et al., 2007). Vegetable oil when used as a fuel cause nozzle choking and coking, gumming, deposition on the piston top, sticking of piston rings and contamination of the lubricating oil (Nadir and Francisco, 2014). Injection problem and poor atomization due to its high viscosity are major problems **(**Bhusnoor, et al., 2007)**.**

Apart from these, starting the engine may become difficult especially in cold weather; because of poor atomization and low volatility of the fuel (Ramadhas and Muraleedharan, 2004 ; Nadir and Francisco, 2014).). There are four ways to use vegetable oil in a Diesel Engine.1. Direct use or blending in Diesel fuel. 2. Micro emulsions in Diesel fuel. 3. Thermal cracking of the vegetable oil. 4. Transesterification. Out of these, transesterification appears to be the most popular and the best way to use a vegetable oil (Bhusnoor, et al., 2007**).** Biodiesel obtained by transesterification process from vegetable oils has been considered a promising option for overcome the above mentioned issues (Bhusnoor, et al., 2007; Nadir and Alpaslan, 2017). The largest possible source of suitable oil comes from both edible and non-edible vegetable oils such as rapeseed, palm or soybean, Mahua, Pongamia, Karanja, Linseed, Jatropha and Neem oil (Babu and Devardjane, 2003).

Biodiesel is the name of a clean burning alternative fuel, produced from straight vegetable oil, animal oil/fats, tallow, waste cooking oil and, renewable resources. Biodiesel contains no petroleum, but it can be blended with petroleum diesel to create a biodiesel blend to use in compression-ignition engines with little or no modifications. From the literature it is observed that the use of biodiesel would gain momentum in the near future. In india automobile industries had initiated an R & D project with an intend to gauge the feasibility of biodiesel generated from the jatropha seeds for which government of India has allotted 100 acres area in Gujarat for planting jatropha.

Different technology tools are used in engineering education to improve the teaching learning process such as flipping the class room with technology and innovative practices of conducting practical and assignments. Generally in practical sessions students are asked to perform the practical on the same setup with common aim. Here the possibility of involvement of all students in a practical and doing individual calculations and analysis is less which may not serve the purpose of the instructor. In this study a group consisting of 4 students is formed and each student in a group is asked to take one entire set of readings at particular load on the engine and instructed to do the calculations individually. Due to which students will learn the use of various measuring instruments and handling of the engine and other accessories, which in turn increased their interest of learning.
This study is focused for the VIth semester undergraduate students in the course of Internal Combustion Engine. The course outcomes which covers this study are Application of the knowledge for testing and analyzing the engine performance parameters and Analysis of exhaust constituents and evaluate requirement of Modern I C Engines for better economy and emissions. In this study

students are trained the biodiesel production process and its utilization in Engine. This activity was encouraged them to learn the course effectively.

2. Methodology:

The steps used in this work are, production of biodiesel, testing the properties of biodiesel and use of biodiesel in I C Engines followed by result and discussion on influence of alternative fuel on engine performance, emissions, socio economic and teaching learning process. selection of the oil for production of biodiesel depends its heating value, viscosity and free fatty acid (Bhusnoor, et al., 2008; Imdadul, et al., 2016).

2.1 Biodiesel Production Process

A biodiesel reactor as shown in Figure 1 is designed and fabricated in the laboratory for production of biodiesel by Transesterification process. In Transesterification process the long and branched chain triglyceride molecules are transformed to monoesters and glycerin. The overall transesterification reaction can be represented by the following reaction (Bhusnoor, et al., 2007)

$$\text{Triglyceride} + \text{Alcohol} \overset{\text{catalyst}}{\longleftrightarrow} \text{Alkyl Ester} + \text{Glycerol}$$

The process of biodiesel production is explained in Figure 2 with the help of flow chart. From the experiments it was observed that the maximum yield, lower viscosity and higher calorific value of biodiesel is obtained for the sample whose reaction time is 180 minutes for oil sample of 200 ml with 96 ml of methanol and 2 gm of KOH. The properties of biodiesel and diesel fuels, as given in Table 1, show many similarities, and therefore, biodiesel is rated as a strong candidate as an alternative to diesel fuel

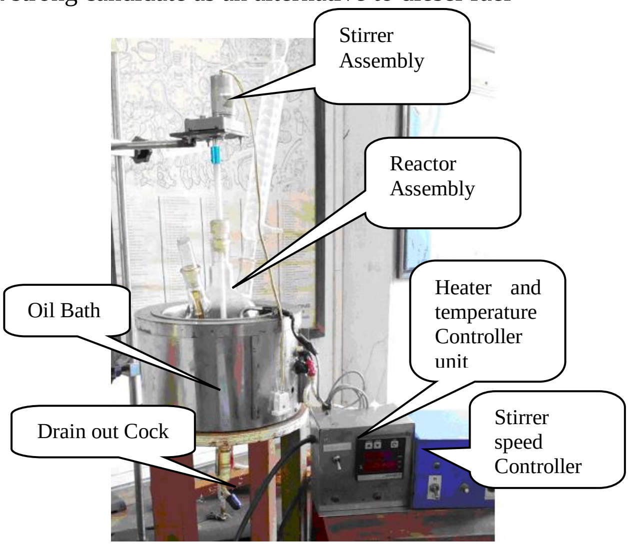

Fig. 1 Biodiesel production setup with Temperature controller and reflux condenser

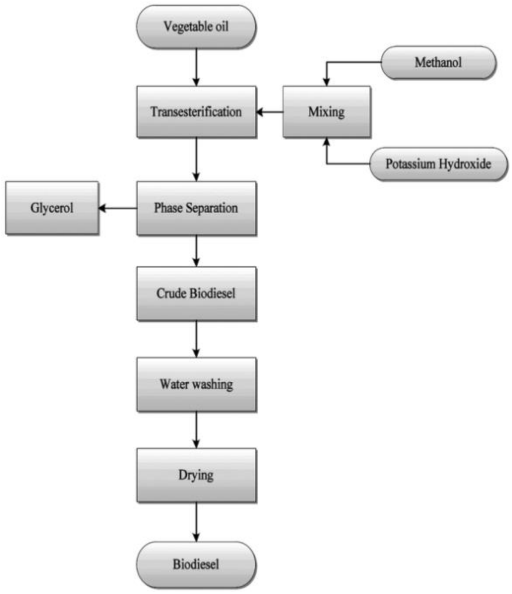

Fig. 2 Flow chart for production of Biodiesel

Table 1. Various Properties of Biodiesel with Diesel fuel

Property	Astm Test	Diesel	Biodiesel
Viscosity (mm^2/s) at 40 °C)	D445	2.86	4.30
Calorific value (MJ/kg)	D240	43.68	39.50
Specific gravity	D1298	0.856	0.889
Flash point (°C)	D93	66	156
Acid Value (mg KOH/g)	D664	0.48	0.87
Distillation Temperature (°C)	D1160	299	350

2.2 Experimentation

A vertical, single cylinder (5 HP, 1500 rpm) air-cooled direct injection diesel engine was used in the experiments. It has the provision of loading mechanically by using rope brake dynamometer. Figure 3 shows the layout of test rig with gas analyser for measurement of engine performance and emission parameters. The main aim of the experimentation is to find out feasibility of using Karanja biodiesel as a partial substitute of diesel oil in a Diesel Engine. The performance and emission test on the engine with these fuels as blends of various proportions ranging from B10 to B60 were evaluated at different load conditions.

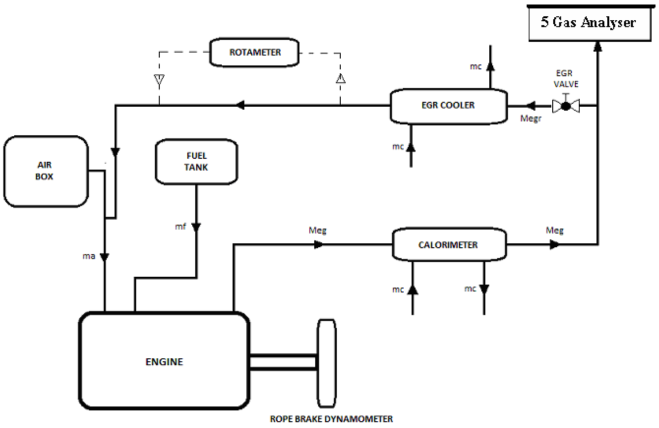

Fig. 3 Line diagram of Engine Experimental setup with Gas Analyzer

2.3 Test Procedure

Before conducting the test, the engine was sufficiently warmed up with the respective test fuels at rated speed. Five different fuel types (D100, B10, B20, B40, and B60) were used to conduct the load test (Constant speed) at different loads ranging from no load to full in a step of 20% of the full load on the engine .Time taken for 10 ml of fuel consumption is noted down for each load condition. During this time, the exhaust gas is sent to the smoke meter and Gas Analyzer, where parameters like smoke intensity, CO, CO_2, HC and NO_X are measured. The data's thus generated is used for calculations of brake specific fuel consumption, thermal efficiency, and other engine performance and emission characteristics.

3. Results and Discussions

Constant speed engine tests were carried out at different loads ranging from no load to full in a step of 20% of the full load on the engine and the following performance and emission variable were analyzed along with economic analysis of the fuel.

3.1 Effect of Biodiesel quantity on the Specific fuel consumption of the engine

Figure 4 shows the brake specific fuel consumption (BSFC) variation for the Diesel fuel and the Diesel Biodiesel blend with respect to engine loads. In general, the BSFC values of the blend were slightly higher than those of the Diesel fuel at all engine loads (Imdadul, et al., 2016). Higher blending is needed to produce the same amount of energy due to its higher specific gravity and lower heating value in comparison to Diesel fuel. However, for the B-20 blend the specific fuel consumption was lower (nearly 6% higher than diesel fuel) as compared to other blends of biodiesel. Also, it was determined that the increase in BSFC values at full load was higher than those at partial loads. Brake-specific fuel consumption of the engine operating on the test fuels in the above figure decreased with increasing operating power. High-engine mechanical efficiency at increasing power levels explained such trends in the brake-specific fuel consumption. Greater brake-specific fuel consumption with the ester fuels was mainly due to the increased fuel flow rather than power (Raheman and Ghadge, 2005; Imdadul, et al., 2016).

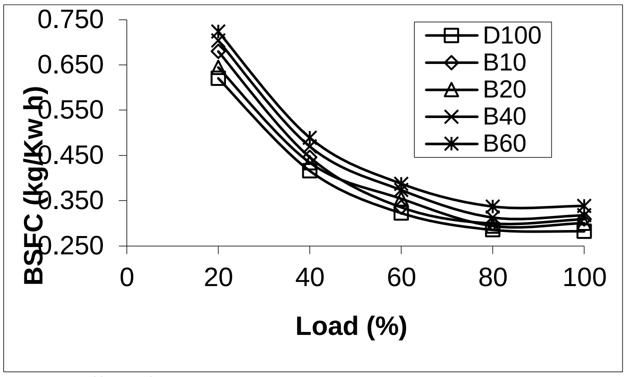

Figure 4 Effect of biodiesel quantity on BSFC

3.2 Effect of Biodiesel Quantity on the Brake Thermal Efficiency of the Engine

The thermal efficiency distribution is shown in Figure 5 for both Diesel Biodiesel blend and diesel fuels. The thermal efficiency of a Diesel engine is inversely proportional to its BSFC and the heating value of the fuel. Since the BSFC values of the blend were slightly higher than those with Diesel fuel, the lower thermal efficiency with the blend was an expected result, which was seen for full load (2.1 % lower than diesel fuel for B20). Although the BSFC values of the blend at partial loads were slightly higher than those with the Diesel fuel, the thermal efficiencies were slightly lower than the diesel fuel due to the lower heating value of the blend.

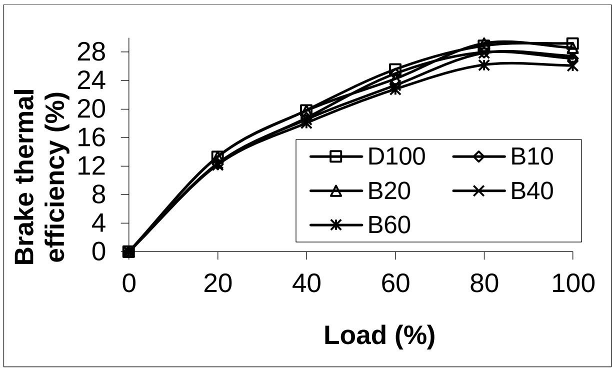

Figure 5 Effect of biodiesel quantity on Brake thermal efficiency

3.3 Effect of biodiesel quantity on exhaust gas temperature of the engine

The variation of exhaust gas temperature with respect to applied load for different fuels tested is shown in above Figure 6. The biodiesel contains some (11% higher than diesel fuel) amount of oxygen molecules in the ester form; it also takes part in the combustion. When biodiesel concentration was increased, the exhaust gas temperature slightly increased. This is due to slow combustion of the linseed oil methyl ester as compared to diesel fuel. The exhaust gas temperature increased with increase in load for all tested fuels. The nitrogen oxides emission is directly related to the engine combustion chamber temperatures, which in turn is indicated by the prevailing exhaust gas temperature. With increase in the value of exhaust gas temperature, NOx emission also increases (Ramadhas and Murlidharan, 2004).

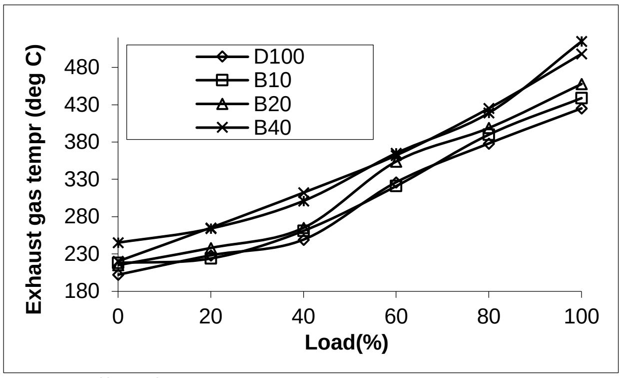

Figure 6 Effect of biodiesel quantity on exhaust gas temperature

3.4 Effect of biodiesel quantity on carbon monoxide emissions from the engine

Figure 7 shows that all the fuels produce low levels of carbon monoxide at lighter load and emit more at higher loads. The carbon monoxide emissions were found to be increase with increase in load. This is typical with all internal combustion engines since the air–fuel ratio decreases with increase in load (Imdadul, et al., 2016).

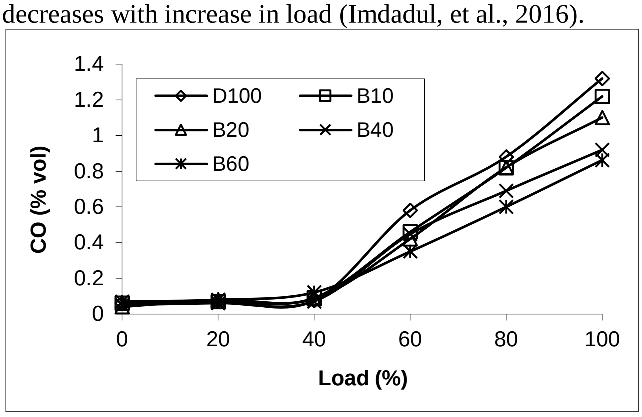

Figure 7 Effect of biodiesel quantity on carbon monoxide emissions

It is interesting to note that, the engine emitted more CO using diesel when compared to biodiesel blends under all loading conditions. With increasing biodiesel percentage, CO emission level decreased by 9%, 42% and 53% relative to diesel with B20, B40 and B60 fuels respectively. Biodiesel itself has about 11% oxygen content in it. This helps to achieve more complete combustion. Hence, CO emission levels decrease with increasing biodiesel percentage in the fuel, which in turn reduces the effect on health and environment (Muralidharan , et al., 2004; Zhang, and Rajasekhar2014).

3.5 Effect of Biodiesel Quantity on Carbon Dioxide Emissions from the Engine

Figure 8 shows the variation of CO_2 emissions with engine load for different fuel blends. It is known that the amount of carbon dioxide emitted is proportional to the amount of fuel burned. The rich fuel mixture in the cylinders at a fixed air fuel ratio brings about the production of more CO_2 at low loads. In addition, at full load, the CO_2 emissions with the blend were higher (3.8,10,16 and21.2% from B10, B20, B40 and B60 fuels respectively) than those with Diesel fuel due to the increase in the mass of fuel injected using the blend and better combustion with the fuel-borne oxygen. At lower loads, the mass difference between the blend and the Diesel fuel injected into the engine was relatively small, and there was more oxygen supplied with the air.

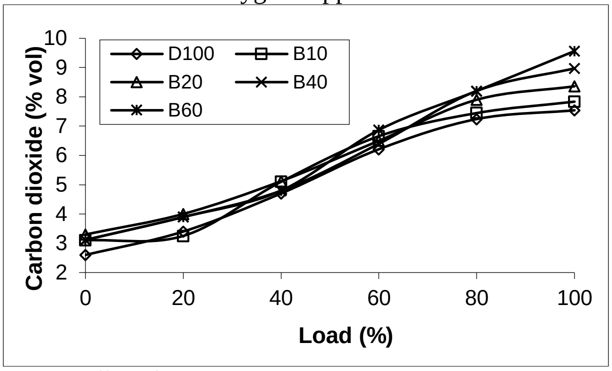

Figure 8 Effect of biodiesel quantity on carbon dioxide emissions

Therefore, the CO_2 emissions of the fuels were very close to each other. Higher CO_2 in exhaust emission is an indication of the complete combustion of fuel. This explains the reason for higher exhaust gas temperatures observed (Imdadul, et al., 2016).

3.6 Effect of biodiesel quantity on emission of smoke from the engine

The variation of smoke density with different fuel blends is shown in Figure 9. Smoke density with biodiesel blends was found to be generally lower (by 6.66, 12.07, 18.7 and 23.3% with B10, B20, B40 and B60 fuels respectively) than with diesel oil. Higher brake power indicates better and complete combustion of fuel. This implies that lower levels of unburned hydrocarbons would be present in the engine exhaust, giving lower smoke density levels with biodiesel blends as compared to diesel (Zhang, and Rajasekhar2014; Imdadul, et al., 2016).

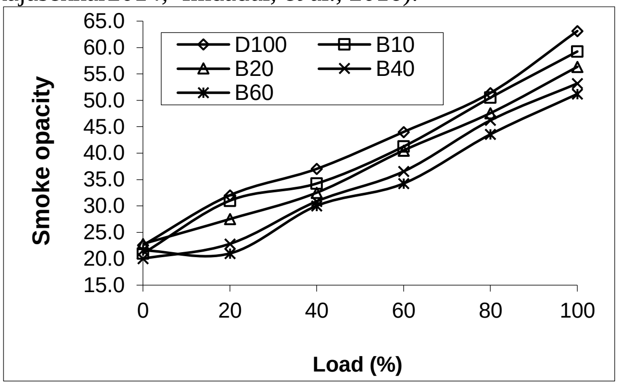

Fig.9 Effect of biodiesel quantity on smoke opacity from the engine

3.7 Effect of biodiesel quantity on emission of Hydrocarbons from the engine

Figure 10 indicates the hydrocarbon emission trends for biodiesel diesel blends and diesel fuel at different engine loads. For efficient combustion, the fuel has to atomize, mix and ignite properly. Fuel viscosity and surface tension affect the penetration rate, maximum penetration and droplet size, which in turn affect the mixing of fuel and air. As the cetane number of ester-based fuel is higher than diesel, it exhibits a shorter delay period and results in better combustion (Canakci and Gerpen, 2001; Zhang, and Rajasekhar, 2014). Therefore, oxygen content and cetane number of the diesel biodiesel blends leads to lower hydrocarbon emissions (4.21, 17.3, 13.9, and 7.98% from B10, B20, B40, and B60 fuels respectively) as compared to diesel fuel. Due to reduction in Hydrocarbon emission there is reduced health hazards and improvement in vehicular pollution.

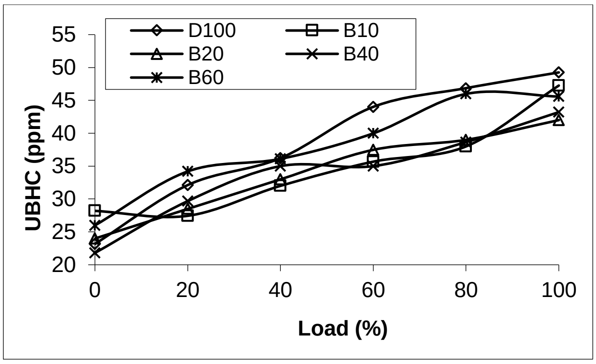

Fig. 10 Effect of biodiesel quantity on emission of UBHC from the engine

3.8 Effect of biodiesel quantity on emission of oxides of nitrogen from the engine

The increase in the local temperature and the oxygen concentration within the fuel spray envelope at increasing power level as mentioned by Springer and Patterson favors the increase in oxides of nitrogen emissions (Kapur, et al., 2006; Zhang, and Rajasekhar2014). Figure 11 indicates the oxides of nitrogen emission trends for biodiesel diesel blends and diesel fuel at different engine loads. The NOx emissions of the blend were slightly higher than those of the Diesel fuel at both full and partial loads. The NOx variation of the blend with respect to engine load showed similar trends with that of the Diesel fuel. The higher temperatures of combustion and the presence of fuel oxygen with the blend caused higher NOx emissions, especially at full load. Higher exhaust temperatures with the blend at full load supported the increase in NOx emissions. There are mainly three factors for the NOx emission, oxygen concentration, combustion temperature and time. Also, it is known that the external oxygen supplied with the air is less effective than the fuel borne oxygen in the production of NOx.

3.9 Impact on Teaching Learning process

Below Figures 12 – 15 shows the improvement of the student score (out of 25 marks) in practical for the year 2017-18 and 2018-19 with respect to the practical score in the year 2013-14. From the figures 12-15, it indicates that inclusion of practical in the course on "use of biodiesel in I C Engines " has improved the student score and learning interest which in turn improved their overall results

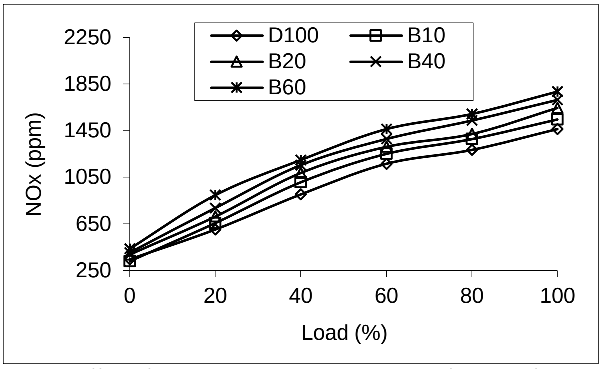

Figure 11 Effect of biodiesel quantity on emission of oxides of nitrogen

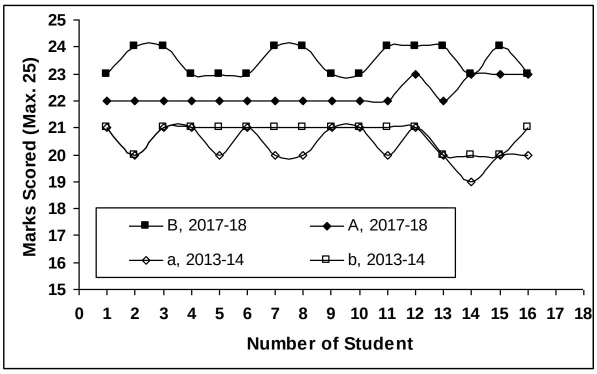

Figure 12. Comparison of marks obtained by the students undergone alternative fuel experiments with that of without alternative fuel experiments for academic year 2017-18

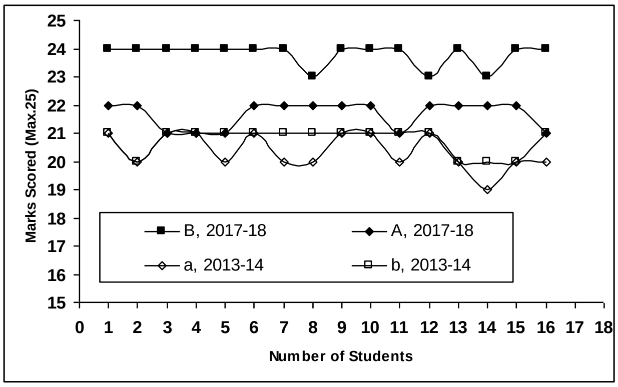

Figure 13. Comparison of marks obtained by the students undergone alternative fuel experiments with that of without alternative fuel experiments for academic year 2017-18

3.10 Fuel Economy Analysis

Fuel consumption for the engine load varying from no load to full was measured for one hour duration to produce a power of one kW continuously. Taking present cost of the Diesel as Rs. 77 per liter and that of for biodiesel as Rs.30 per liter as per the market price in India, the cost analysis per kW hr power production was carried out as shown in Figure16. From the figure 16, it is clear that due to increase in biodiesel composition from B10 to B60 there is decrease in fuel cost almost 37%. It is also tested by using B100 fuel; cost was reduced by 55%. This indicates that use of biodiesel will reduce the cost of the fuel and improve the fuel economy and emissions

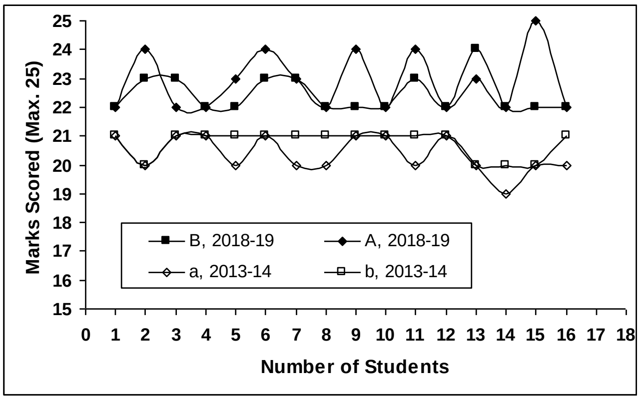

Fig. 14 Comparison of marks obtained by the students undergone alternative fuel experiments with that of without alternative fuel experiments for academic year 2018-19

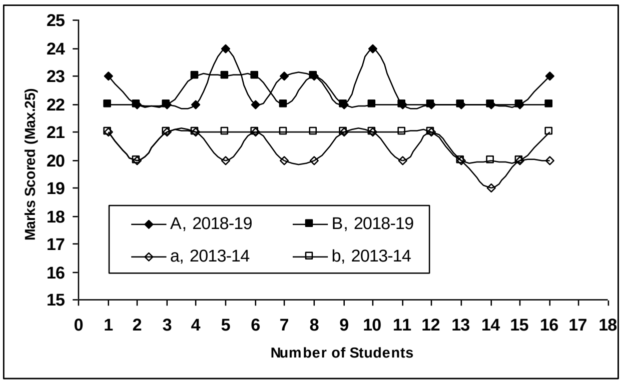

Fig. 15 Comparison of marks obtained by the students undergone alternative fuel experiments with that of without alternative fuel experiments for academic year 2018-19

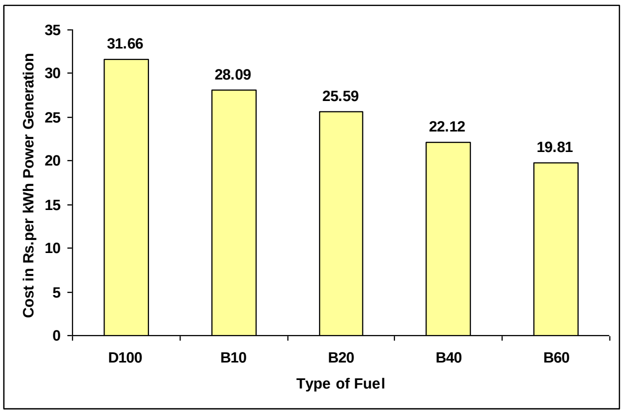

Fig. 16 Comparison of Cost (Rs) of Diesel and Diesel Biodiesel Blends for producing power of one kW for one hour.

4. Conclusions

The present results obtained shows that, the transesterification process improved the fuel properties of the oil with respect to specific gravity, viscosity, flash point and acid value. The comparison of these properties with diesel shows that no hardware modifications are required for handling this fuel (biodiesel) in the existing engine. Biodiesel is proved to be a potential candidate for partial substitute of mineral diesel oil.

Based on the above study one can conclude that due to this type of hands-on practice, students will develop an ability to describe and design a process for experimentation and analyze and interpret the data and communicate it effectively to the society. From the results it also reveals that PO1 to PO4 and PO6 and PO7 are maximally satisfied, PO11 and PO12 are moderately satisfied, where as PO5, PO8, PO9 and PO10 are weekly satisfied by this activity.

Acknowledgment

The authors like to take this opportunity to express their sincere regards and profound sense of gratitude to Shri. Samir Somaiyaji (Trustee, Somaiya Trust), Principal Dr. Shubha Pandit, Vice- Principal Dr. N R Gilke and HOD of Mechanical Engineering Dr. Ramesh R. Lekurawale, for their valuable suggestions, encouragement and support in carrying out this work. Authors extend their gratitude's to Prof. Sangeeta Kulkarni and Prof. Rachana Desai for their guidance throughout this work. The authors also would like to thank Faculty of Mechanical Engineering Department of KJSCE and staff of I C Engine Laboratory, Mr. R M Katkar for their self less guidance and help in conducting the experiments.

References

1. Babu, A.K., Devardjane, J. (2003) Vegetable oils and their derivatives as fuels for C.I. Engines: An overview, SAE 2003, 0100767, 406-417
2. Bhusnoor, S.S**.,** Babu, M.K.G. and Subrahmanyam, J.P. (2007) Studies on Performance and Exhaust Emissions of a CI Engine operating on Diesel and Diesel Biodiesel blends at different Injection Pressures and Injection Timings, *SAE*, 2007-01-0613
3. Bhusnoor, S.S., Babu, M.K.G and Subrahmanyam, J.P. (2006) Optimization of Transesterification Process for Biodiesel Production from Linseed Oil, *SAE, 2006-28-0046.*
4. Bhusnoor,S.S., Babu, M.K.G and Subrahmanyam, J.P. (2008) Characterization and Lubricity Testing (SRV Wear Tester) of Diesel and Diesel Biodiesel (LOME) Blends,*SAE,2008-28-0042.*
5. Canakci, M. and Gerpen J.V. (2001) Biodiesel Production from Oils and Fats with high Free Fatty Acid, Transaction ASAE, 44(6), 1429–36
6. Imdadul, H.K., Masjuki, H.H., Kalam, M.A. , Zulkifli, N.W.M. , Abdullah, A., Rashed, M.M., Teoh, Y.H. and How, H.G. (2016) Higher alcohol–biodiesel–diesel blends: An approach for improving the performance, emission, and combustion of a light-duty diesel engine, Energy Conversion and Management, 111, 174–185.
7. Kapur, G . S., Sarpal, A.S., Sarita, G, and Mookken RT. (2006) A Protocol for Unambiguous identification of Components in Synthetic Ester based Lubricants using Modern NMR Experiments, SAE 2006, 28(0045), 1-6.
8. Muralidharan, M., Mathew P., Thariyan, Sumit R, Subbarao, P.M.V., and Subrahmanyam, J,P. (2004)

Use of Pongamia Biodiesel in CI Engines for rural application, SAE 2004-28-0030

9. Nadir, Y. and Francisco, M. V. (2014) Potential use of a blend of diesel, biodiesel, alcohols and vegetable oil in compression ignition engines, Fuel ,124, 168–172.
10. Nadir, Y. and Alpaslan, A. (2017) Experimental assessment of a diesel engine fueled with diesel-biodiesel-1-pentanol blends, Fuel, 191,190–197.
11. Raheman H, Ghadge VS., (2005) Biodiesel Production from Mahua (Madhuca Indica) oil having high Free Fatty Acids, Biomass and Bioenergy, 28, 601–605
12. Ramadhas, A.S., Jayaraj, S. and Murlidharan. C. (2004) Use of vegetable oils as I.C. engine fuels – A review, Renewable Energy, 29, 727–742.
13. Ramadhas A.S. Jayaraj S, Murlidharan, C. (2005) Characterization and effect of using Rubber Seed Oil as Fuel in Compression Ignition Engines, Renewable Energy, 30, 795-803
14. Zhang, Z. and Rajasekhar, B. (2014) Influence of butanol addition to diesel–biodiesel blend on engine performance and particulate emissions of a stationary diesel engine, Applied Energy, 119 , 530–536.