Assessing the Performance of Diesel Engine Using Bio-diesel Produced from Mustard Oil Locally Available in Pakistan

Abdul Hameed Memon
Energy engineering department, Hamdard University Karachi, Sindh Pakistan
ahameed_memon@hotmail.com

Asif Ali
Mechanical engineering department, Quaid-e- Awam University College of Engineering, Science & Technology, Larkana Sindh Pakistan

Muhammad Adeel, Muhammad Tahir, Muhammad Junaid, Awais Ahmed
Mechanical engineering department, Quaid-e- Awam University of Engineering, Science & Technology (QUEST) Nawabshah Sindh Pakistan

Abstract
Continuous depletion of conventional fuels has emphasized to find the alternate energy resources. For this, biodiesel is being considered as one of the potential alternative for future. Previous studies have highlighted various sources for production of bio-diesel. This study investigated the potential of using mustard oil cultivated in Pakistan as a source for bio-diesel production to cope with ever increasing problem of energy crises. Mustard seed is an indigenous crop cultivated in Pakistan. Presently mustard oil is used for both edible and non-edible purposes. Reactive distillation technique was used for preparation of Bio-diesel from Mustard oil. A lab scale Sieve –Tray reactive distillation reactor system was designed and fabricated locally. Bio-diesel so produced from mustard oil available locally was used for assessing the performance of diesel engine. Bio-Diesel was produced using Methanol to oil ratio of 4:1 (Molar) and column temperature of 650C. It was then mixed with petro-diesel in different proportions and used as fuel for diesel engine. The practical results showed that the biodiesel can be blended with diesel and used for running diesel engines without any modification in the engine. It was found that the ratio as high as 80% Bio-Diesel with 20% Petro-Diesel gave better performance of diesel engine.

Keywords
Bio-diesel, Mustard Oil, Diesel Engine

1. Introduction

Shortage of energy is key problem faced by the world today. One of the major reasons for this is depletion in conventional energy resources in use. Besides this, various environmental issues associated with these resources are also major concern for the society. Further, the emissions of harmful gases by combustion of petroleum based oils have led to search for alternative fuels (Radha *et. al.*, 2011]. Nakpong and Wootthkanokkan (2010) and Kumar *et. al.* (2014) stressed that alcohols like ethanol& methanol are easy to produce but these are highly corrosive and need modifications in the existing parts of the engines. This is also a key issue under consideration of the governments around the world to look for some alternatives which are not only available in nature but are also environment friendly. Various researchers in investigating the different options during last few decades for resolving this issue suggested using Bio-diesel as one of potential alternative fuel for future. Bio-diesel has been reported for better engine performance and environmental friendly as compared to fossil based fuels (Peterson, et. al., 1979, Canakci and Jon, 2000).

Vegetable oils or animal fats are the basic source for production of biodiesel oil using trans-esterification or alcoholysis, enzymatic or lipase conversion and thermal cracking of pyrolysis. Trans-esterification of vegetable oils with methanol or ethanol in presence of catalyst is most commonly used method for production of biodiesel. Researchers in different countries have focused on different vegetable oils for production of biodiesel considering it as fuel of future. Depending upon soil conditions various vegetable oils are being studied in different countries for example in USA soya bean oil, in European counties sun flower oil, in Malaysia and Indonesia palm oil are being considered as substitute of diesel oil in future (Srivasta and Prasad, 2000). Study of mechanism and kinetics of biodiesel production showed that trans-esterification consists of a number of consecutive reversible reactions (Freedman et. al., 1984, Noureddini and Zhn, 1997). In this process, firstly Triglycerides are reduced to diglycerides and subsequently to mono-glycerides and finally to fatty acids to get esters & glycerols. Because of reversible reaction, in order to maintain the equilibrium to product excess alcohol is used. Consequently, Glycerol obtained as by product can be used for many industrial applications such as cosmetics, pharmaceuticals etc. This process results in reduction in the viscosity of oils comparable to diesel.

Investigating batch trans-esterification process of winter rapeseed oil, Peterson *et. al.* (1991) found that 6:1 molar ratio of methanol to oil gave best conversions in 60 minutes. Maximum conversions were achieved in 15 minutes when a ratio of 6 moles of methanol per mole of oil and 0.3% of NaOH (Ma, et. al. 1998). Peanut, cotton seed and sun flower oils were trans-esterified using ratio of 6 moles of methanol per mole of oil and 0.5% of sodium methoxide at 600C where 80% yield was observed after 1 minute on soyabean & sunflower oils (Freedman *et. al.,* 1984). Also, biodiesel obtained from mustard oil is a suitable fuel for diesel engines (Forhad, *et. al.* 2009).

The present study focuses on the production of biodiesel from indigenous oil seeds of Mustard oil. Mustard is cultivated in almost all parts of Pakistan and presently used for both edible and non-edible purposes. Also, rape seeds are important species of Brassica genus belonging to family Brassica are grown as oil seeds crops in Pakistan. These too remained one of the major sources of oil used for both edible and non-edible purposes in the subcontinent for centuries. Presently five species of Brassica are cultivated in the country as field crops. These include Brassica campestris (local name Sarson), B. juncea (local name Raya), B. nigra (local name Kali sarson), Brassica napus (Canola) and Brassica alba (Chitisarson). All these species are cultivated in various soil conditions as well as drought tolerant soils due to high yield. Another variety is called as Jambho or taramira. Rape seed and mustard seed contain 38-41% oil and 28% protein. Taramira contains about 34% oil. Mustard being most commonly cultivated crop in Pakistan was selected as the source for the present study.

2. Experimental procedure: preparation of biodiesel

Biodiesel can be produced from vegetable oil by different processes such as pyrolysis, micro emulsification, dilution and trans-esterification. In present work trans-esterification was used for preparation of biodiesel from mustard oil, This process is also known as alcoholysis where an alcohol is used in presence of a catalyst to break an ester into methyl or ethyl ester and glycerol as by product. Trans-esterification depends upon free fat acid and moisture content (Forhad, *et. al.* 2009). Trans-esterification reaction for vegetable oil is given below.

$CH_2-OOC-R_1$ $\qquad\qquad\qquad\qquad$ $R_2-OOC-R'$ $\quad$ CH_2-OH

$$CH-OOC-R_2 + 3R'OH \rightleftharpoons R_2-OOC-R' + CH_2-OH$$

$$CH_2-OOC-R_1 \qquad R_3-OOC-R' \qquad CH_2-OH$$

$$\text{Triglyceride + Alcohol} \rightleftharpoons \text{Ester + Glycerol}$$

In the present study reactive distillation (RD) technique was used, a technique where simultaneous implementation of chemical reactions and distillation in a counter current column is adopted. The operation of RD depends upon several factors that include size of reaction and separation zone, reflux ratio, feed rate and tray location (Solokhin and Blagov, 1996; Tuchlenskia et. al., 2001). Omata et al (2003) highlighted conceptual design of reactive distillation of fatty acid esterification and mentioned that either tray or packed columns may be used for RD process. However, tray columns are recommended and therefore in present work tray column was designed and fabricated. The general set-up of RD technique applied into biodiesel preparation in trayed column is illustrated in figure 1.

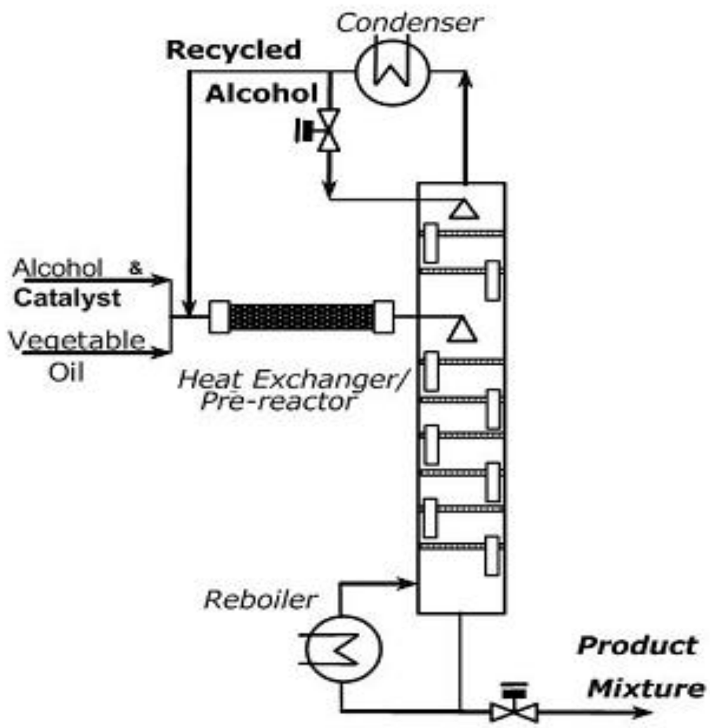

Figure 1: Sketch of Reactive Distillation Unit (Reproduced from He, 2006)

In the setup illustrated in figure 1, tray in column forms a reactive zone. Oil and methanol & catalyst are introduced from top of the column which flows downwards and experience counter current gas-liquid contact with upward flow of methanol vapors from re-boiler flask. Performance of a continuous flow RD unit was studied which showed that the above set up produces better results for methanol to oil ratio of 4:1 (molar) and column temperature of 650C. The biodiesel produced under these conditions met ASTM standards (Singh, 2013).

3. Results and discussion

3.1 Biodiesel productivity

The study focused on assessing the performance of engine with respect to processing time in distillation unit. In preparation for each trail, stock alcoholic KOH was prepared with composition of 1% KOH w/w of oil for each given methanol-to-oil molar ratio, and placed in a holding reservoir separately. Likewise Mustard seed (Rapeseed oil) was held in a separate heated reservoir maintained at 500C, and methanol at atmospheric temperature. The flow of both methanol and oil from the corresponding reservoirs was calibrated to get the required methanol to oil ratio. Oil and methanol mixture was filled in the re-boiler and re-boiler was heated till the temperature of column reached at 650C. After achieving the required temperature levels of the all units of the system, each valve was switched on to get flow of the raw feed into the mixer chamber and re-boiler chamber. Feed rate of mixture was maintained as 0.61 liters/min in proportions of 0.43 liters/min of oil and 0.08 liters/ min of methanol mixed with KOH equal to 1% of oil. The performance of unit for various processing times is presented in table 1 where it shows that for processing time of 4 minutes the performance of the unit was better as compared to 5 min and 8 min processing time in achieving percentage production of 95% (by volume).

Table 1: Performance of the unit for various processing time

Observation	Processing Time		
	8 min	5 min	4 min
Feed mixture `(liter)	4.88	3.05	2.5
Product Mixture (Liter)	4.68	2.85	2.45
Bio-diesel (Liter)	4.48	2.65	2.4
Glycerine (Liter)	0.2	0.2	0.05
Recovered Methanol (Liter)	0.2	0.2	0.05

3.2 Diesel Engine performance

Experimental investigations were conducted to study the sustainability of the Bio-diesel produced from mustard oil as fuel for Diesel engine. Slow speed Diesel Engine Test bed Model DWE- 6/10¬JS-DV available in the laboratory was used to conduct the tests to investigate the effect of blending of Bio-diesel with Petro-diesel in different proportions. The specifications of the engine test bed used are given in table 2.

Table 2: Example table for demonstration

Type	Water cooled 4 cycle diesel engine Horizontal type
Number of cylinders	1
Bore	80 mm
Stroke	95 mm (477 cc)
Compression ratio	23:1
Out put	2200 rpm (Max.)
Torque indicator	Load Cell
Fuel consumption meter	Skewer type 3- burrets of 5, 10, 20 cc)

Bio-Diesel produced from Mustard oil was used in blending with Petro-diesel. Various blends in proportion of ranging from 30% to 90% of Bio-diesel were used. Effect on the speed of the engine for different blending proportions at different brake loads is shown in figure 2.

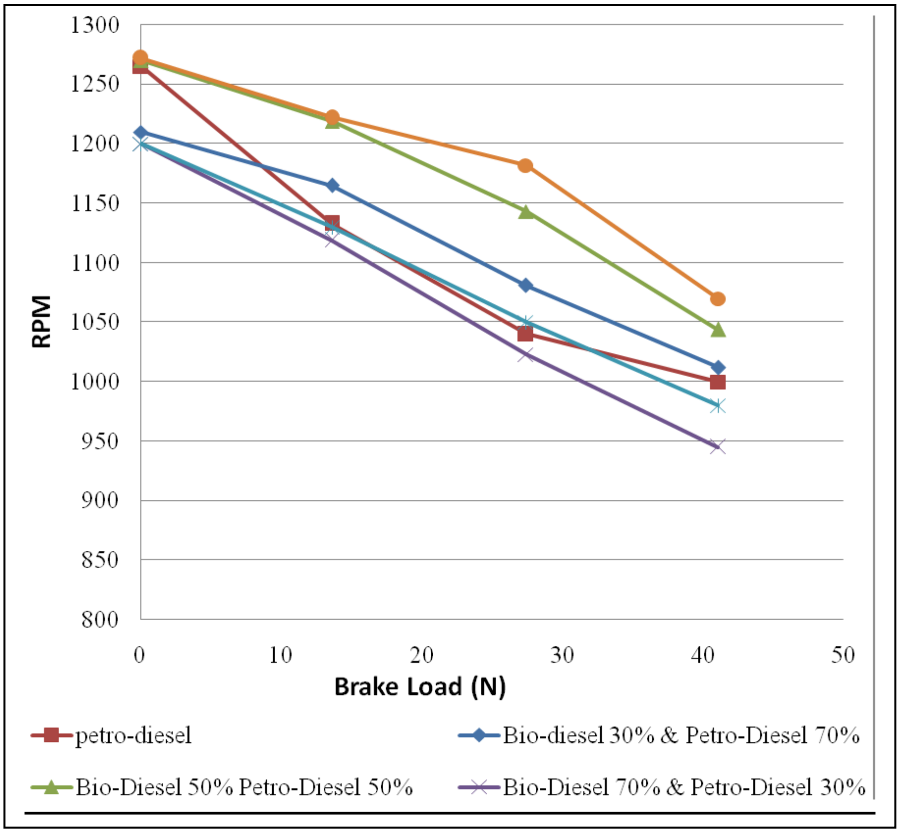

Figure 2: Effect on RPM at different Brake Loads for different fuels

Figure 2 shows that the results exhibits same trend in terms of change in speed with brake load. These curves indicate that RPM of the engine has inverse proportion with brake load. For 90% blending of biodiesel exhibited higher RPM as compared to other proportions. In order to investigate the effect of brake load on fuel consumption, time consumed for combustion of 5 ml of fuel was recorded the results obtained are presented in figure 3 where the results from figure 3 show that specific fuel consumption of biodiesel is higher as compared to the petro diesel. This could be due to higher viscosity of biodiesel blends as compared to petro diesel causing poor atomization which results in higher fuel consumption rate. Exhaust gas temperature with variation in brake load is presented in figure 4 where the curves depict that in all the cases higher values of exhaust gas temperature were noticed for all proportions of blend as compared to petro diesel. This could be due to delay in combustion of high proportion of biodiesel at the start of the process causing higher exhaust gas temperatures with consequent loss of heat energy.

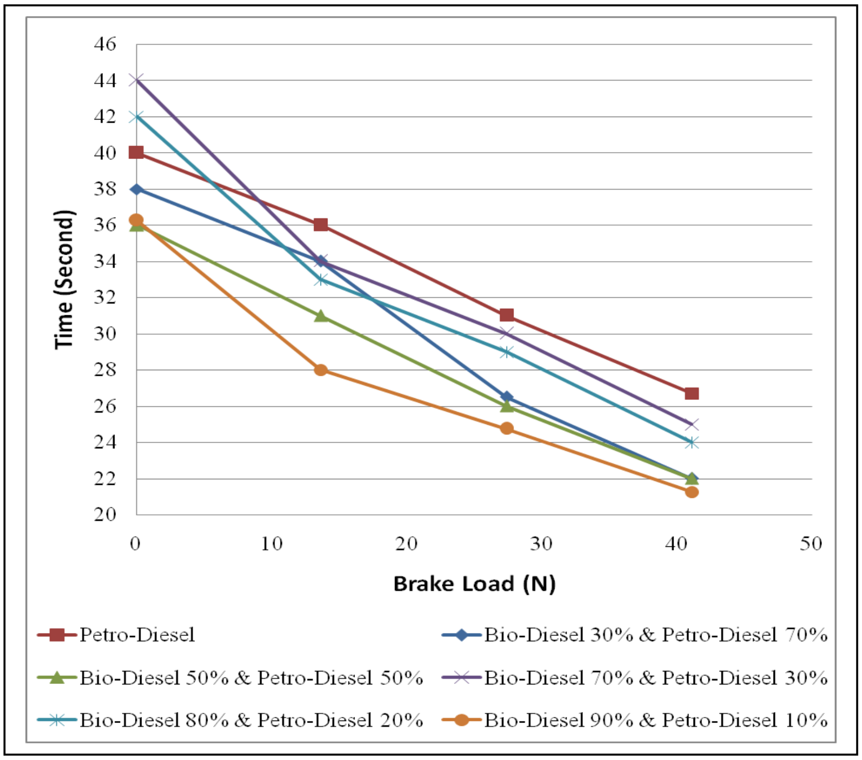

Figure 3: Effect of Fuel Consumption (5 ml/time) at different load for different fuels

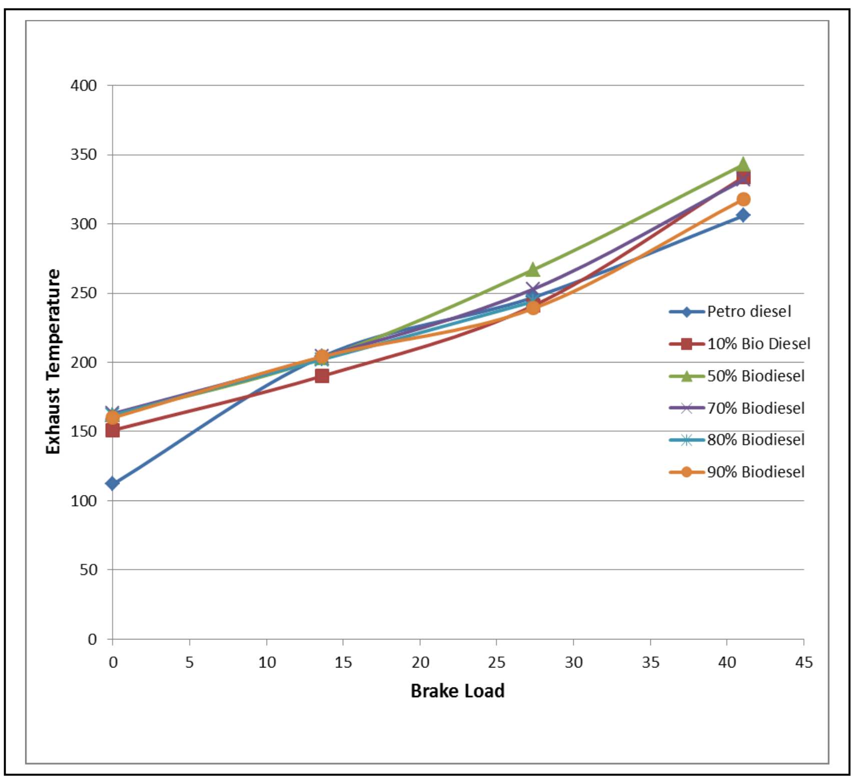

Figure 4: Effect on exhaust gas temperature at different Brake Loads for different fuels

4. Conclusion

From the results obtained during the present study, it is concluded that

- Laboratory scale RD unit was developed which could be helpful to the student for understanding operational parameters of the unit.
- Although costly in the present set-up, mustard oil could be considered an alternative source of energy by converting it in to biodiesel.
- Biodiesel produced from mustard oil blended with diesel showed satisfactory performance as fuel for diesel engine without any modification in the engine.
- Blending proportion of 70% biodiesel was found to be more appropriate for use in diesel engine.
- Further investigations may be conducted by preheating biodiesel before entering the combustion chamber; this may help in overcome problem of initial delay in combustion and reduce exhaust losses

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