ISSN: 2186-8476, ISSN: 2186-8468 Print
Vol. 1 No. 4, December 2012

PERFORMANCE AND EXHAUST EMISSION CHARACTERISTICS OF A DI ENGINE FUELED WITH NEEM OIL METHYL ESTER (BIODIESEL) AND ITS BLENDS WITH DIESEL

Sylvester Gadimoh[1], **Mahdi Makoyo**[2]

[1] National Research Institute for Chemical Technology, Zaria,
[2] Department of Mechanical Engineering, Faculty of Technology, Bayero University, Kano, NIGERIA.
gadimohs@rocketmail.com

ABSTRACT

Energy is an essential and vital input for economic activity. Building a strong base of energy resources is a pre-requisite for the sustainable economic and social development of a country. Transport vehicles which is one of key player in development of a country, greatly pollute the environment through emissions such as CO, CO2, NOx,SOx, unburnt or partially burnt HC and particulate emissions. Fossil fuels are the chief contributors to urban air pollution and major source of green house gases (GHGs) and considered to be the prime cause behind the global climate change. Biofuels are renewable, can supplement fossil fuels, reduce GHGs and mitigate their adverse effects on the climate resulting from global warming. Biodiesel (fatty acid methyl esters) is produced by transesterification in which, oil or fat is reacted with a monohydric alcohol in presence of a catalyst. (Schuchardt et al., 1998). This paper presents the steps in biodiesel production and the results of performance and emission analyses carried out in an unmodified diesel engine fueled with neem methyl ester (NME) and its blends with diesel. Engine tests have been conducted to get the comparative measures of brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC) and emissions such as CO_2 *to evaluate the behaviour of NME and diesel in varying proportions. The results reveal that blends of NME with diesel up to 40% by volume (B40) provide better engine performance (BSFC and BSEC) and improved emission characteristics.*

Keywords: Biodiesel, Transesterification, neem methyl ester, Exhaust emission, Fossil fuel.

INTRODUCTION

Energy is an essential and vital input for economic activity. Building a strong base of energy resources is a pre-requisite for the sustainable economic and social development of a country. Indiscriminate extraction and increased consumption of fossil fuels have led to the reduction in underground-based carbon resources. Biofuels will mitigate the vulnerability and the adverse effects of use of fossil fuels. Several developed countries have introduced policies encouraging the use of biofuels made from grains, vegetable oil or biomass to replace part of their fossil fuel use in transport in order to achieve the following goals; to prevent environmental degradation by using cleaner fuel, to reduce dependence on imported, finite fossil supplies by partially replacing them with renewable, domestic sources and to provide new demand for crops to support producer income and rural economics.

The neem oil has less calorific value than that of diesel due to the oxygen content in their molecules. Researchers such as Zejewski M, Goettler H, Pratt GL.(1986) show that high viscosity, density, iodine value and poor non volatility are the problems associated with the use of vegetable oils in diesel engines leading to problems in pumping, atomization and gumming, injector fouling, piston and ring sticking and contamination of lubricating oils in the long run operation. Hence, it is essential to reduce the viscosity of the vegetable oils by methods such as preheating, thermal cracking and transesterification, pyrolysis, microemulsification (co-solvent blending). Trans-esterification is the best way to convert the vegetable oils to suit for the use in diesel engines, Srivastava A, Prasad R.(2000) and Schwab, A.N. et al (1987)..

Biodiesel is a variety of ester-based oxygenated fuels derived from natural, renewable biological sources such as vegetable oils. It's name indicates, use of this fuel in diesel engine alternate to diesel fuel. Biodiesel operates in compression ignition engines like petroleum diesel thereby requiring no essential engine modifications. Moreover it can maintain the payload capacity and range of conventional diesel. Biodiesel fuel can be made from new or used vegetable oils and animal fats. Unlike fossil diesel, pure biodiesel is biodegradable, nontoxic and essentially free of sulphur and aromatics.

Advantages of Biodiesel

a. Produced from sustainable / renewable biological sources
b. Ecofriendly and oxygenated fuel
c. Sulphur free, less CO, HC, particulate matter and aromatic compounds emissions
d. Income to rural community
e. Fuel properties similar to the conventional fuel
f. Used in existing unmodified diesel engines
g. Reduce expenditure on oil imports
h. Non toxic, biodegradable and safety to handle

Biodiesel is produced by transesterification of large, branched triglycerides into smaller, straight chain molecules of methyl esters, using an alkali or acid or enzyme as catalyst. There are three stepwise reactions with intermediate formation of diglycerides and monoglycerides resulting in the production of three moles of methyl esters and one mole of glycerol from triglycerides. The overall reaction is: (see Figure 1).

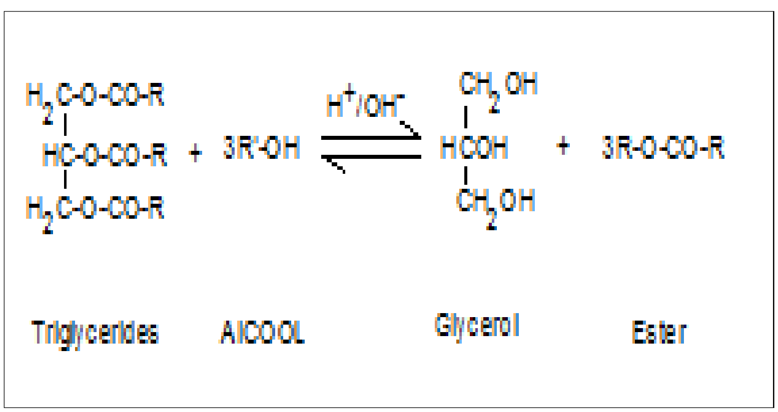

Figure 1. General equation for a transesterification reaction

Alcohols such as methanol, ethanol, propanol, butanol and amyl alcohol are used in the transesterification process. Methanol and ethanol are used most frequently, especially methanol because of its low cost, and physical and chemical advantages. They can quickly react with triglycerides and sodium hydroxide is easily dissolved in these alcohols. Stoichiometric molar ratio of alcohol to triglycerides required for transesterification reaction is 3:1. In practice, the ratio needs to be higher to drive the equilibrium to a maximum ester yield.

Several aspects, including the type of catalyst (alkaline or acid), alcohol/vegetable oil molar ratio, temperature, purity of the reactants (mainly water content) and free fatty acid content have an influence on the course of the transesterification (Freedman et al., 1984; Srivastava and Prasad, 2000; Ma and Hanna, 1999).

MATERIALS AND METHODS

Biodiesel Production Materials

Biodiesel and the various blends were produced with the biodiesel pilot plant of 600ltrs capacity at the National Research Institute for Chemical Technology (NARICT), Zaria. Mtaterials used for the biodiesel production includes; Neem oil, Methanol, sodium hydroxide, phenolthanyle indicator, water, etc. The fossil diesel was purchased from Total filling station club road kano.

Engine Test Materials

The experimental set up consists of a three cylinder four-stroke, constant-speed (1500 rpm) direct ignition engine. The detailed specification of the engine is given below. Specification of diesel engine Name of the manufacturer: Perkins, Rated speed: 1500 rpm, Brake power: 20 KVA, Efficiency of the generator: 82% Fuel used: Diesel Rated voltage on generator: 220-440 V. An exhaust gas analyser, model AUTO 5-1 by M/s Kane International Ltd., (UK) is coupled to this engine for measuring the various emission parameters. A separate fuel tank of capacity 5 liters was fitted with the diesel engine for the bio-diesel and its blends. A schematic diagram of the experimental setup is shown in Figure 2.

EXPERIMENTION

Test Procedure

A series of experiments were carried out using diesel, biodiesel and the various blends made in National Research Institute for Chemical Technology (NARICT), Zaria. All the blends were tested under varying load conditions (no load to 75% of the rated maximum load) at the rated speed in accordance with IS:10,000 (Part VIII).. During each trial, the engine was started and after it attains stable condition, important parameters related to thermal performance of the engine such as the time taken for 20 cm^3 of fuel consumption, applied load, the ammeter and voltmeter readings were measured and recorded and the exhaust gas temperature from the online exhaust gas analyser were noted and recorded.

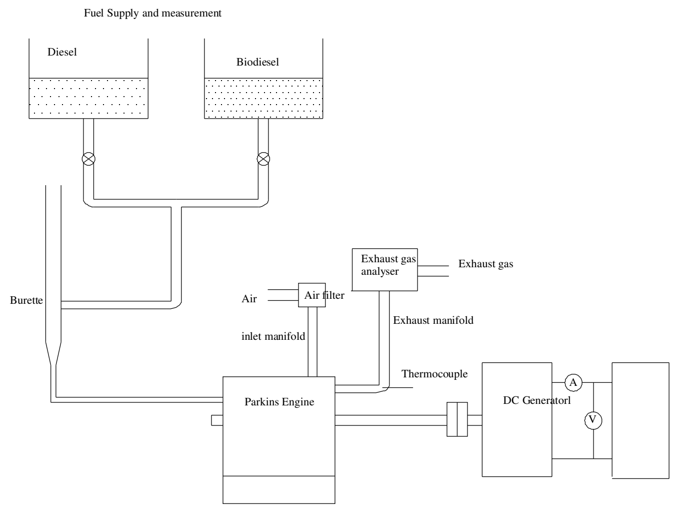

Figure 2. Experimental setup

RESULTS AND DISCUSSION

Characteristics of Biodiesel and Its Blends

After the transesterification process, the colour of NME changed from deep brown to reddish yellow. The properties of the NME measured were compared with other biodiesel and presented in Table 1.

Table 1. Properties of the Neem oil Biodiesel produced (Test conducted at NNPC, R&D Division, Port Harcourt, Sample code: PPQT 1397-1398, Date 23/12/08)

S/No	Test	Unit	Methods	Neem Oil Biodiesel
1	Appearance		VISUAL	Free-Flowing Brown Liquid
2	SG. @ 60 ^oF		ASTM D-1298	0.8940
3	API gravity		ASTM D-287	26.78
4	Flash point	^oC	ASTM D-92/93	172
5	Cloud point	^oC	ASTM D-2500	21
6	Carbon residue	Wt %	ASTM D-524	0.5
7	Pour point	^oC	ASTM D-5853	12
8	Kinematic Viscosity @ 40^oC	cSt	ASTM D-445	8.2
9	Aniline point	^oC	ASTM D-611	27
10	Diesel Index		IP 21	21.6

It is seen from Table 1 that the specific gravity and calorific values of NME are in closer agreement with the other biodiesel and the kinematic viscosity and flash points are comparatively higher. In comparison with diesel, the flash point and fire point were found to be around three times more, facilitating safe transport and storage. The colorific value of NME was measured to be 36 MJ/kg, which is less than that of diesel (41.86 MJ/kg) and greater than that of raw neem oil (34.0 MJ/kg). The kinematic viscosity of the NME was measured to be four times that of diesel at 40 ^{0}C. The property values of different blends with increasing concentration of NME (0–100%) are shown in Figs. 2 and 3.

It is observed that increasing concentration of NME in the diesel resulted in the corresponding remarkable increase in the kinematic viscosity. A similar phenomenon in specific gravity is also noted. The flash point of the various blends with increasing NME concentration is found to increase due to the higher value of flash point for NME than diesel. Conversely, a decreasing trend was observed for the calorific value in the fuels with increasing NME concentration.

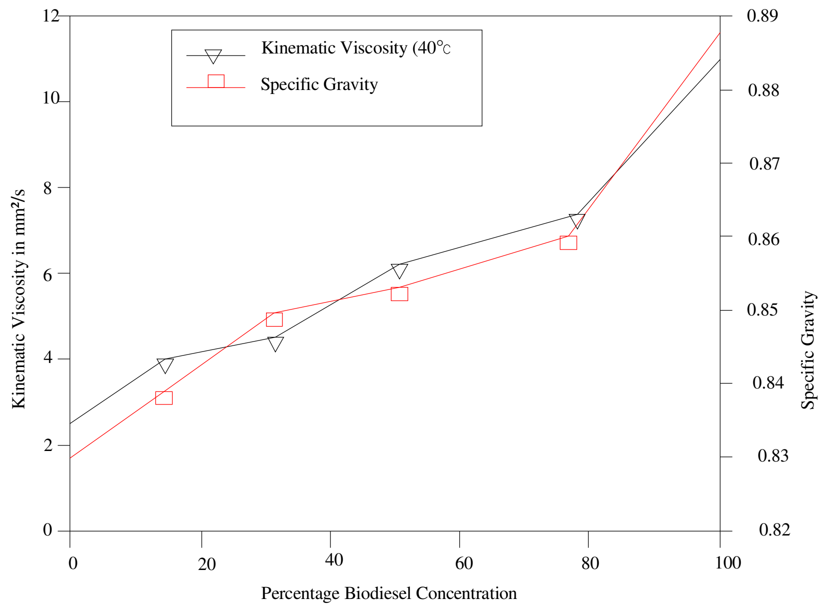

Figure 3. Fuel blend properties (kinematic viscosity and specific gravity)

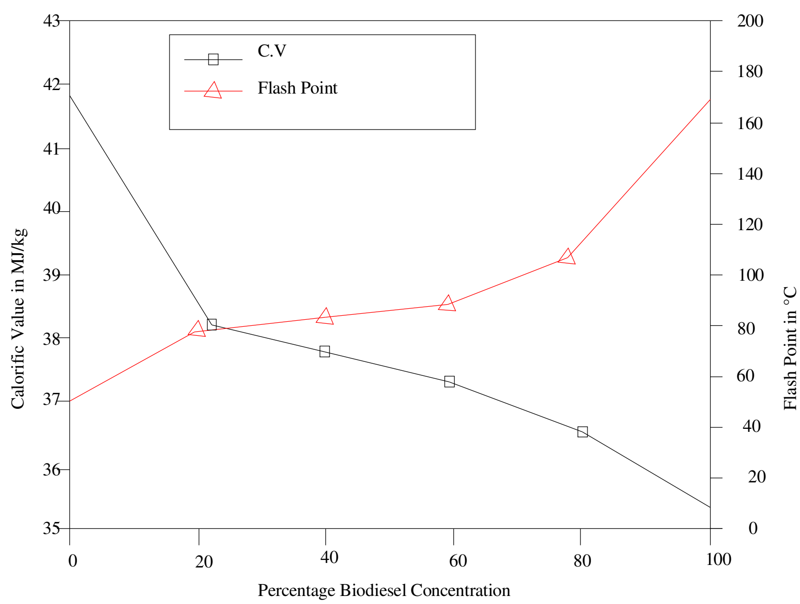

Figure 4. Fuel blend properties (calorific value in MJ/kg and flash point in ^{0}C)

Engine performance

The engine performance and emission tests were carried out in accordance with IS:10,000 (Part VIII). The

engine performance was evaluated based on brake specific fuel consumption (BSFC) and brake specific energy

consumption (BSEC) to compare the various blends of NME and diesel with diesel.

BSFC and BSEC

The variation of BSFC and BSEC with load for different blends and diesel are presented in Figures 5 and 6. It is observed from Figures 5 and 6 that the BSFC and BSEC for all the fuel blends and diesel tested decrease with increase in load. This is due to higher percentage increase in brake power with load as compared to increase in the fuel consumption. For the blends B20 and B40, the BSFC is

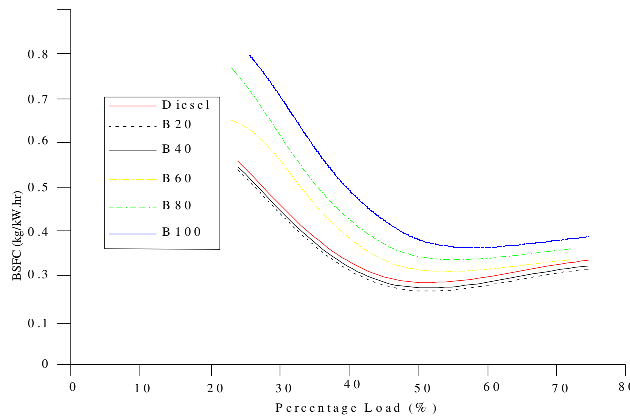

Figure 5. Variation of BSFC with load for different blends

lower than and equal to that of diesel, respectively, and this enables complete combustion and the negative effect of BSEC is less than that of diesel at all loads. This could be due to the presence of dissolved oxygen in the NME that enables complete combustion and the negative effect of the increased viscosity could not have been initiated. However, as the NME concentration in the blend increases.

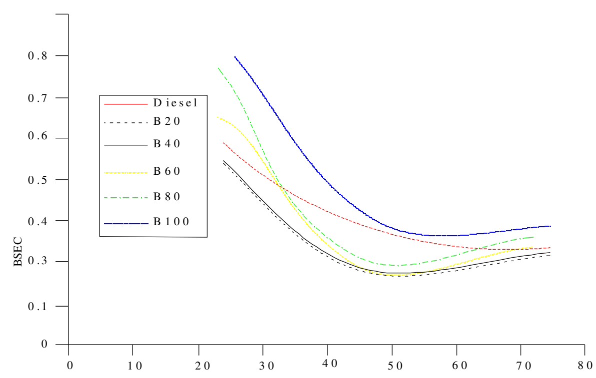

Figure 6. Variation of BSEC with load for different blends

further, the BSFC increases at all loads and the percentage increase is higher at low loads. Whereas the BSEC for all the fuels tested increases initially at low loads and at higher load conditions, its value is less than that of diesel for all the blends and more than that of diesel for NME. This could be due to the lower calorific value of the NME and the high mass flow of fuel entering into the engine (specific gravity of NME is 6% more than diesel). Also, the engine has been designed only for diesel fuel and has been used for NME in an unmodified condition. In addition, the high viscosity of the blends may also inhibit the proper atomization of the fuel, which in turn affects the combustion process.

Engine emission studies

CO_2 Emission

The CO_2 emission increased with increase in load for all blends. The lower percentage of NME blends emits less amount of CO_2 in comparison with diesel. Blends B40 and B60 emit very low emissions. This is due to the fact that biodiesel in general is a low carbon fuel and has a lower elemental carbon to hydrogen ratio than diesel fuel. Using higher content NME blends, an increase in CO_2 emission was noted, which is due to the incomplete combustion as explained earlier. Though at higher loads, higher biodiesel (NME) content blends emit CO_2 almost the same with fossil diesel, in general biodiesels themselves are considered carbon neutral because, all the CO_2 released during combustion had been sequestered from the atmosphere for the growth of the vegetable oil crops.

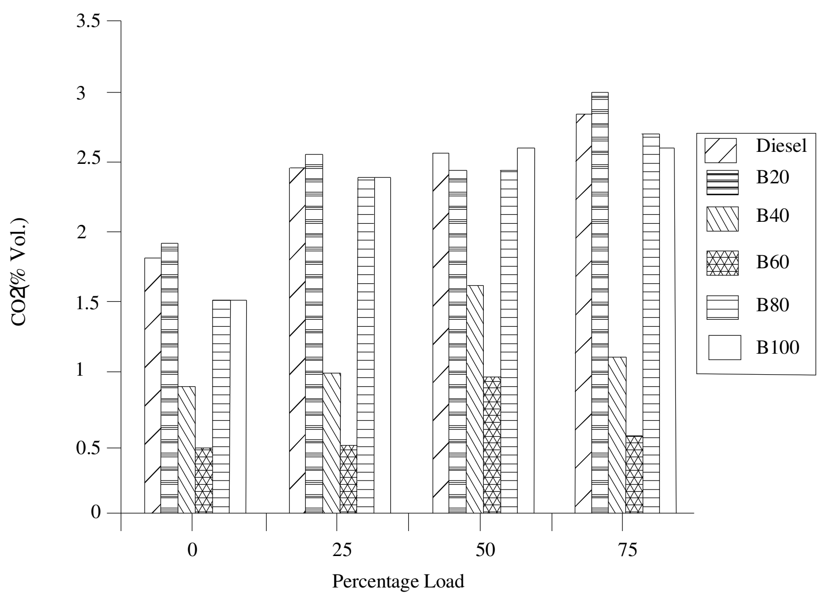

Figure 7. Variation of CO_2 emission with load for different blends

Exhaust gas temperature

The variation of exhaust gas temperature for different blends with respect to the load is indicated in Figure 8. The exhaust gas temperature for all the fuels tested increases with increase in the load. The amount of fuel injected increases with the engine load in order to maintain the power output and hence the heat release and the exhaust gas temperature rise with increase in load. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber. At all loads, diesel was found to have the highest temperature and the temperatures for the different blends showed a downward trend with increasing concentration of NME in the blends. This is due to the improved combustion provided by the NME due to its 11% dissolved oxygen content.

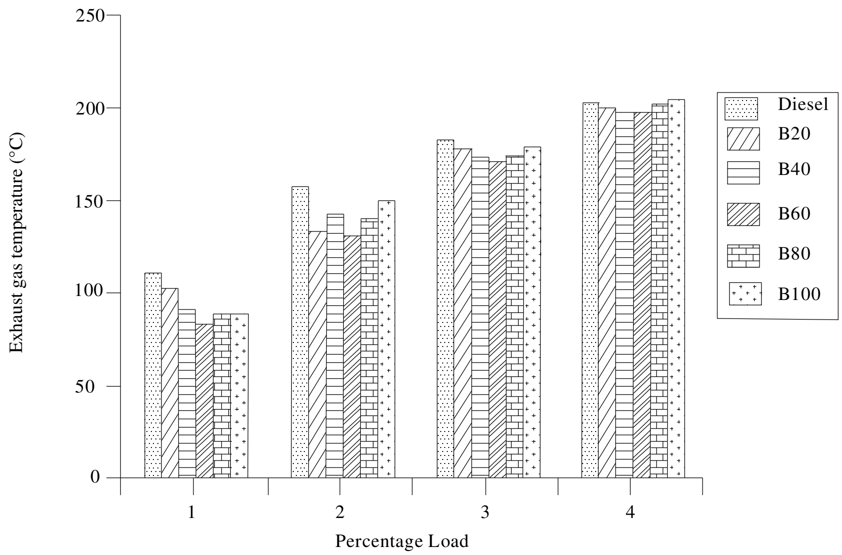

Figure 8. Variation of Exhaust gas temperature with load for different blends

CONCLUSION

The aim of the present investigation was to analyse the usability of NME as a replacement to diesel in an unmodified DI engine. It was found that blends of NME and diesel could be successfully used with acceptable performance and better emissions than pure diesel up to a certain extent. From the experimental investigation, it is concluded that blends of NME with diesel up to 40% by volume (B40) could replace the diesel for diesel engine applications for getting less emissions and better performance and will thus help in achieving energy economy, environmental protection and rural economic development. In the near future conventional fuels will be fully replaced by biodiesel and will provide a viable solution for the much threatening environmental pollution problems.

REFERENCES

Burnwal, B.K., Sharma, M.P. (2005). Prospects of biodiesel production from vegetable oils in India. *Renewable Sustainable Energy Reviews*, 9: 363–378.

Demirbas, A. (2005). Biodiesel production from vegetable oils via catalytic and non-catalytic supercritical methanol transesterification methods. *Prog Energy Combust Sci*, 31, 466–487.

Dorado, M.P., Ballesteros, E., Arnal, J.M., Gomez, J., Lopez, F.J. (2003). Exhaust emissions from a diesel engine fueled with transesterified waste olive oil. *Fuel*, 82 (11), 1311–1315.

Freedman, B., Butterfield, R. O., Pryde, E.H. (1984). Variables affecting the yields of fatty esters from transesterified vegetable oils. *Journal American Oils Chemistry Society*, 61, 1638.

Karmee, S.K., Chala, A. (2005). Preparation of biodiesel from crude Pongamia pinnata. *Bioresour Technology*, 96(13), 1425–1429.

Kumar, S.M., Ramesh, A., Nagalingam, B. (2003). An experimental comparison of methods to use methanol and jatropha oil in a compression ignition engine. *Biomass Bioenergy*, 25(3), 309–318.

Ma, F., Hanna, M. A. (1999). Biodiesel production: a review. Bioresource Technology, 70(1), 1-15.

Schuchardt, Ulf., Sercheli, R., Vargas, R.M. (1998). Transesterification of vegetable oils: a Review. *Journal of the Brazilian Chemical Society*, 9(1), 199-210.

Schwab, A.W., Bagby, M.O. and B. Freedman (1987). Preparation and Properties of Diesel Fuels from Vegetable Oils. *Fuel* 66(10), 1372–1378.

Senatore, A., Cardone, M., Rocco, V., Prati, M.V. (1999). A comparative analysis of combustion process in D.I. diesel engine fueled with biodiesel and diesel fuel. Transactions of SAE, SAE 1999-01-1497.

Srivastava, A., Prasad, R. (2000). Triglycerides-based diesel fuels. *Renewable Sustainable Energy Reviews*, 4(2),111–133.

Zejewski, M., Goettler, H., Pratt, GL. (1986). Influence of vegetable oil based alternative fuels on residue deposits and components wear in a diesel engine. SAE 860302 1986:297–307.