COMPARISON OF THE PERFORMANCE AND EMISSIONS OF DIFFERENT BIODIESEL BLENDS AGAINST PETROLEUM DIESEL

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Abstract:

Biodiesel, a petroleum diesel replacement, is utilised to lower emissions without changing engines. Using an internal combustion engine (Kubota V3300) and ISO 8178 criteria, this research compares the performance and emissions of various biodiesel mixes with petroleum diesel. This research examined two forms of biodiesel: type A (80% tallow/20% canola oil methyl ester) and type B (80% chicken tallow/30% waste cooking oil methyl ester). The performance (primarily torque and braking power) of both biodiesel fuels decreases with increasing mix ratio, perhaps due to biodiesel's reduced energy content. As predicted, both biodiesels have higher specific fuel consumption than diesel. Some of the emissions were greater than petroleum diesel, while others were lower. Overall, Biodiesel A has fewer emissions than diesel and Biodiesel B.

1. Introduction:

It is commonly known that petroleum diesels pollute the air and contribute to global warming. Biodiesel offers several advantages over petroleum diesel, including producing 4.5 units of energy per unit of fossil energy [1, 2] and being non-toxic, biodegradable, and safer to breathe [3].Biodiesel is also a steady and clean fuel [3].

The oxygen concentration, cetane number, viscosity, density, and heat value of biodiesel are highly dependent on the source (soybean, rapeseed, or animal fats) [4, 5]. Biodiesel affects engine performance and emissions. Biodiesel is a highly oxygenated fuel that may minimise unburnt hydrocarbons, carbon dioxide, carbon monoxide, sulphur dioxide, nitric oxide, and polycyclic aromatic hydrocarbon emissions. But brake-specific fuel consumption rises [6].

Due to increasing environmental consciousness and rising diesel prices, biodiesel is rapidly gaining popularity as a sustainable alternative fuel. It is a consumer-friendly solution that already accounts for a large portion of the global fuel market.

The need to minimise greenhouse gas emissions is driving many nations' biodiesel fuel development, and the shortage of petroleum diesel fuel is also driving global biodiesel fuel development. Transesterification is a chemical process used to create biodiesel from vegetable or animal fats.

Rudolf Diesel (1858-1913) utilised vegetable oil to operate his first engine. Because of their higher viscosity and lower volatility than diesel fuel, vegetable oils might have harmful effects on engine components [4, 5, 7]. Currently, this issue is being addressed by converting vegetable oils into biodiesel using a variety of chemical techniques.

This article compares the engine performance (power, torque, fuel consumption) and emissions (unburnt HCs, CO2, CO, and NOx) of two different biodiesels. The research tested two types of biodiesel: type A (80% tallow (beef, pig, and sheep) and 20% canola oil methyl ester) and type B (80% chicken tallow and 30% waste cooking oil methyl ester). The B5, B10, B20, B50, and B100 fuel types are covered.

2. THEORETICAL CONSIDERATION:

Compression ignition (CI) engines are evaluated for performance by operating them at various loads and speeds. Engine performance is affected by the testing circumstances and whether the engine is completely or partially loaded. Pressure, temperature, and humidity affect power output [8]. Increasing the volumetric efficiency improves the quantity of air available for combustion in the ICE. This raises the MEP, which raises the engine's power output. For a four-stroke engine, we have:

$$\mathrm{ip} = \frac{\mathrm{MEP} \times V_s \times Nn}{2}$$

1

where ip is the specified power (in kW), which is the rate of work done by the gas on the piston of the engine [8]. Vs is the engine's swept volume (air flow rate), N its rev/s, and n its cylinders. Gas expansion and compression laws may be used to calculate the airflow rates for naturally and force aspirated running. The equation below may be used to compute the natural aspiration flow rate (Vi).

$$V_\mathrm{i} = V_\mathrm{s} \times I \times \eta_\mathrm{vol}, \quad \text{where } I = \frac{2N}{\text{strokes/cycle}}$$

2

The volumetric efficiency, hvol, is believed to be independent of engine speed. To make things even simpler, we may assume that the airflow limits are in the compressor and ICE head, not the filter and ducting.The following equation may be used to calculate airflow.

$$p_\mathrm{f} = p_0 \times \varepsilon^k$$

3

where pf is the air flow rate (m3/s) and 1 is the compression ratio.The volume of air within the cylinders, Vi, is not equal to Vs. The ICE compression ratio (1) is:

$$\varepsilon = \frac{V_\mathrm{s} + V_\mathrm{c}}{V_\mathrm{c}}$$

4

$$\varepsilon_\mathrm{effective} = \frac{V_1 + V_\mathrm{c}}{V_\mathrm{c}}$$

5

engine clearance volume (m3) Similarly, the forced charge (under atmospheric circumstances) is compared to the swept volume using standard and effective volumetric efficiencies. Aspirated efficiency is provided by

$$\eta_\mathrm{vol} = \frac{V_\mathrm{i}}{V_\mathrm{s}}$$

6

$$\eta_{\mathrm{vol}_\mathrm{effecitive}} = \frac{V_\mathrm{comp}}{V_\mathrm{s}}$$

7

Variables such as mixture strength, compression ratio, specific enthalpy of vaporisation of the fuel, heating of the induced charge, cylinder temperature and valve timing impact volumetric efficiency.
The beginning conditions for compressions (with the piston at BDC) are as follows:

$$V_\mathrm{i} = \eta_\mathrm{vol} \times V \quad \text{and} \quad p_0 = p_\mathrm{a} \times \eta_\mathrm{vol}^k$$

8

$$V_\mathrm{i} = V_\mathrm{comp} \quad \text{and} \quad p_0 = p_i \times \eta_\mathrm{vol}^k$$

9

3. EXPERIMENTAL CONSIDERATION

The performance and emissions of test fuels were investigated using a Kubota V3300 indirect injection four cylinder naturally aspirated CI engine (Figure 1). It produces 50.7 kW at 2600 rpm and 230 Nm at 1400 rpm. Table 1 provides the Kubota V33 specs. The three major metrics that describe a diesel engine's performance are braking power, torque, and specific fuel consumption. This is the mass flow rate of gasoline used per unit power produced. A dynamometer measures braking power and torque. A fuel flow metre measures the flow rate of gasoline to the engine to determine specific fuel consumption. A torque is derived from an absorption dynamometer by

Figure 1. Experimental set-up of Kubota V3300 Indirect Injection, four cylinders naturally aspirated CI engine

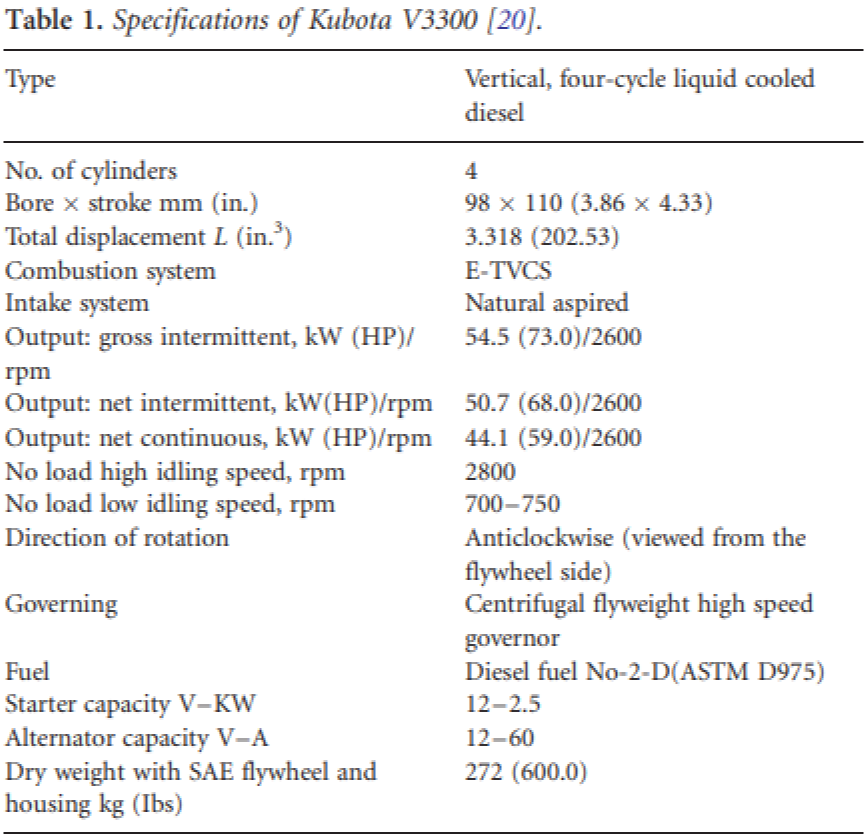

Table 1. *Specifications of Kubota V3300 [20].*

Type	Vertical, four-cycle liquid cooled diesel
No. of cylinders	4
Bore × stroke mm (in.)	98 × 110 (3.86 × 4.33)
Total displacement L (in.^{3})	3.318 (202.53)
Combustion system	E-TVCS
Intake system	Natural aspired
Output: gross intermittent, kW (HP)/rpm	54.5 (73.0)/2600
Output: net intermittent, kW(HP)/rpm	50.7 (68.0)/2600
Output: net continuous, kW (HP)/rpm	44.1 (59.0)/2600
No load high idling speed, rpm	2800
No load low idling speed, rpm	700–750
Direction of rotation	Anticlockwise (viewed from the flywheel side)
Governing	Centrifugal flyweight high speed governor
Fuel	Diesel fuel No-2-D(ASTM D975)
Starter capacity V–KW	12–2.5
Alternator capacity V–A	12–60
Dry weight with SAE flywheel and housing kg (Ibs)	272 (600.0)

$$T(\text{Torque}) = WR$$

10

$$\text{Brake power (bp)} = 2\pi NT$$

11

$$\mu_{\mathrm{M}} = \frac{\mathrm{bp}}{\mathrm{ip}}$$

12

An Andros 6241A, 5 gas analyser was used to measure exhaust gas emissions. This EGA takes immediate measurements of an exhaust gas sample. A non-dispersive infrared sensor monitors oxygen, CO2, CO, and HCs. An electrochemical sensor monitors nitric oxide in this model.

The blends utilised in this research were B5, B20, B50, and B100, with biodiesel percentages of 5%, 20%, 50%, and 100%. This research employed two forms of biodiesels: type A (80% tallow (beef, pig, and sheep) and 20% canola oil methyl ester) and type B (80% chicken tallow and 30% waste).This research employed the ISO 8178 test process, which is an eight-mode steady-state test procedure that includes three engine speeds: rated, intermediate, and low idle. Each test mode is 10 minutes long, with emissions recorded in the final 3 minutes. The engine is preconditioned for 40 minutes at rated power before each test cycle, and at least 50 data are collected for each mode in each test cycle, with three cycles per test fuel.2600 and 1400 rpm were tested.

4. RESULTS AND DISCUSSION

Because biodiesel is denser than petroleum diesel, its fuel consumption is projected to be greater . Biodiesel from palm oil is more efficient than biodiesel from tallow and canola oil. In comparison to petroleum diesel, biodiesel has a lower gross calorific value (energy content). Biodiesel/petrol blends are frequently utilised in diesel engines. Fuel viscosity causes fuel flow and ignition issues in unmodified CI engines, as well as reduced power. These biodiesels are superior in lubricity and oxidative stability than soy-based biodiesels. Animal methyl esters are distinct from vegetable methyl (ethyl) esters.Results of this research (Biodiesels A and B) vs diesel performance and emissions are detailed below.

4.1 Torque and power:

Figure 2 displays torque vs diesel and biodiesel mixes for Biodiesels A and B using ISO 8178 modes 1 and 5. Mode 1 corresponds to the rated engine speed (2600 rpm) at full throttle, while mode 5 corresponds to the intermediate engine speed (1560 rpm) at full throttle. The other modes need the torque to be adjusted to a value (thus lowering the throttle from 100%) that is the same for all test fuels. Figure 2 shows that the output torque decreases with increasing biodiesel mix ratio. In these circumstances, both biodiesels lose 4–5% of their energy content. The decreased energy content of biodiesel is to be anticipated. Because torque and power are directly related while the engine speed is constant, the drop in output torque reduces the engine's power output. As a consequence, power output drops by 4–5%. The reduced energy content of biodiesel causes a loss of power and torque.

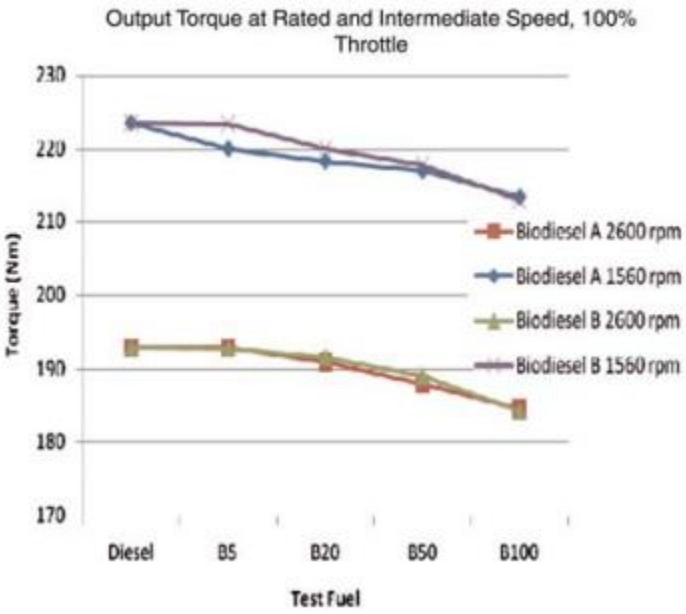

Figure 2. Torque comparison for different biodiesel blends [B5(5% biodiesel 95% diesel), B20 (20% biodiesel 80% diesel), B50 (50% biodiesel 50% diesel) and B100 (100% biodiesel)] using Biodiesel A (80% beef, pork and sheep

tallow and 20% waste cooking oil methyl ester) and Biodiesel B (70% chicken tallow and 30% waste cooking oil methyl ester).

4.2 Specific fuel consumption:

The specific fuel consumption of two biodiesels using ISO 8178 test process. This test process may be used to determine fuel usage as well as exhaust pollutants.During testing, the fuel flow rate was monitored in each mode, and the average of the three tests for each fuel was calculated using the test procedure's weighting parameters.Because the test process dictates torque and rpm, fuel consumption should be greater for lower energy fuels.Figure 3 shows that for both Biodiesel A and B, fuel consumption rises with blend ratio. Fuel consumption is 10% greater for Biodiesel B than for Biodiesel A, indicating that Biodiesel B contains less energy than Biodiesel A, and both biodiesels have less energy than diesel.

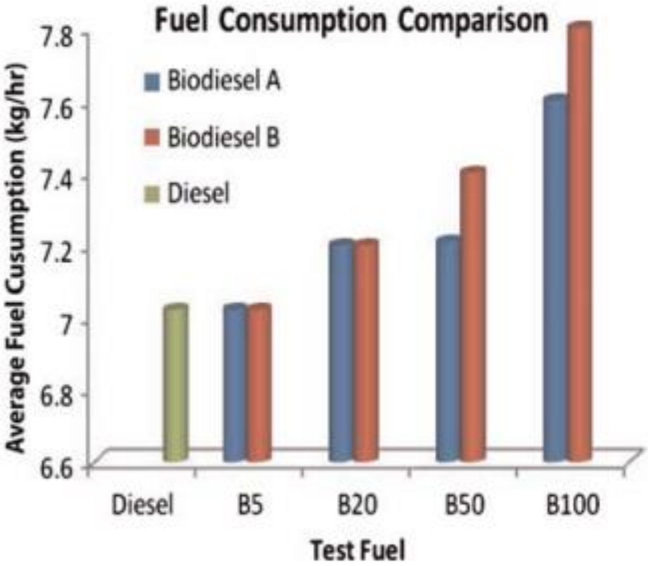

Figure 3. Fuel consumption comparisons.

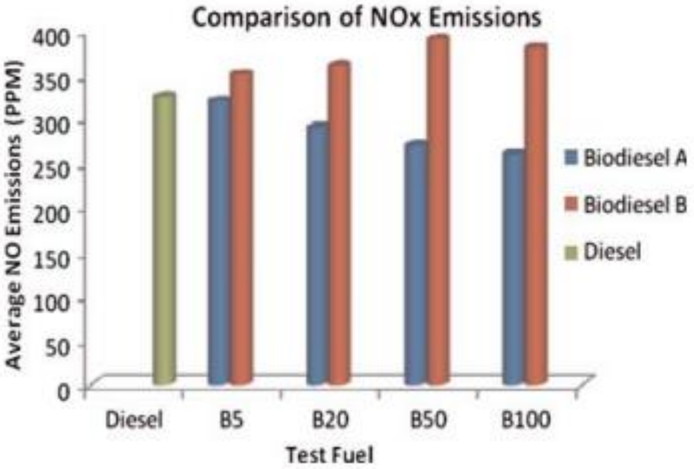

Figure 4. Comparison of NOx emissions.

4.3 Exhaust emissions:

Biodiesel A, Biodiesel B, and diesel are shown in Figure 4. Biodiesel A nitric oxide emissions decrease with increasing blend ratio, but Biodiesel B nitric oxide emissions rise. NOx emissions might rise or decrease depending on the biodiesel, engine, and testing process. The US EPA says B100 emits 10% more NOx than diesel.

On the ISO 8178 test technique, Figure 5 displays the CO emissions for Biodiesel A and B. Increasing the mix percentage of both biodiesels reduced CO emissions. The reduction is 55% for Biodiesel A and 30% for Biodiesel B.

The US EPA [4] claimed a 51% reduction in CO emissions from biodiesel. This might be because biodiesel has more oxygen than diesel, resulting in a more complete combustion and less CO in the exhaust stream.

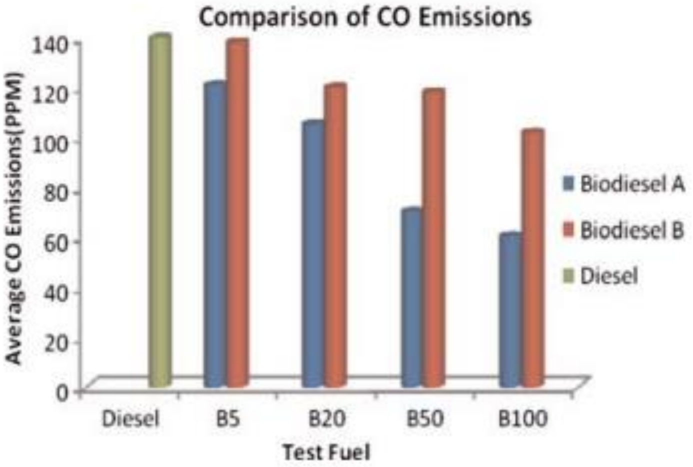

Figure 5. Comparison of carbon monoxide emissions.

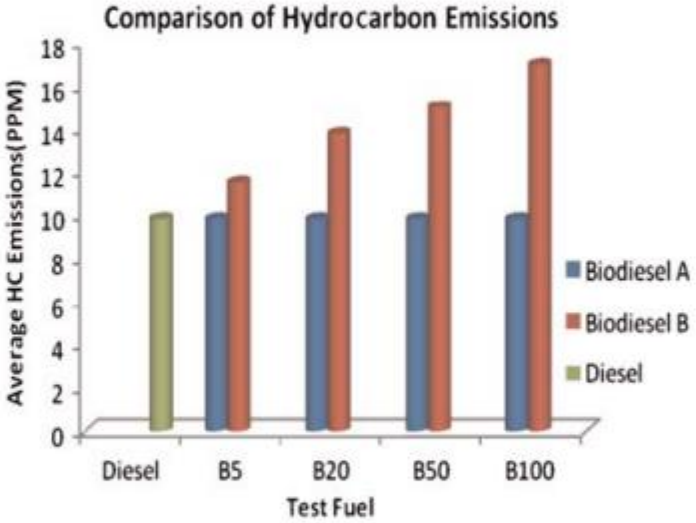

Figure 6. Comparison of HC emissions

Figure 6 shows the biodiesel HC emission values. As can be observed, both Biodiesel A and B emit more HC as the mix ratio increases.According to the EPA, HC should decrease as the mix ratio increases. The HCs detected during testing were relatively low (,0.002 percent). Other investigations have shown much greater quantities of HCs in diesel exhaust emissions, calling these findings into doubt. The EGA is specialised for detecting petrol engine exhaust emissions, not diesel. Petrol engine emissions include more HC than diesel engine emissions. Rather of the infrared sensor employed in this research, an exact measurement of diesel/biodiesel HCs would need a flame ionisation detector, which is quite costly. Inaccurate HC measurements might also be due to HC drift. This allows the HCs to break down into other compounds like CO2 and water vapour. Because the sample point is 3 m down the exhaust stream on the test rig, it is probable that some of the HCs have broken down and so a lesser quantity is being detected.

Figure 7 illustrates the carbon dioxide emissions during the ISO 8178 biodiesel test. Both biodiesels show a rise in CO2 emissions with increasing blend ratios, despite the fact that a drop in CO2 emissions was predicted based on Figure 5. The increase is 6% for Biodiesel A and 18% for Biodiesel B compared to diesel. CO2 is an unregulated (unlimited) emission that is routinely detected in exhaust gas analysis because it indicates fuel usage in dynamometer testing . Biodiesel has been proven to reduce CO emissions by up to 51%, but it may either raise or decrease CO2 emissions by up to 7% depending on the type. The present investigation revealed that Biodiesel A emits less CO than the literature suggests, but Biodiesel B emits more CO2. Because CO2 emissions are not controlled, this difference is not important.This study's biodiesels (Biodiesels A and B) increased CO2 emissions, although the reasons for this require further research.

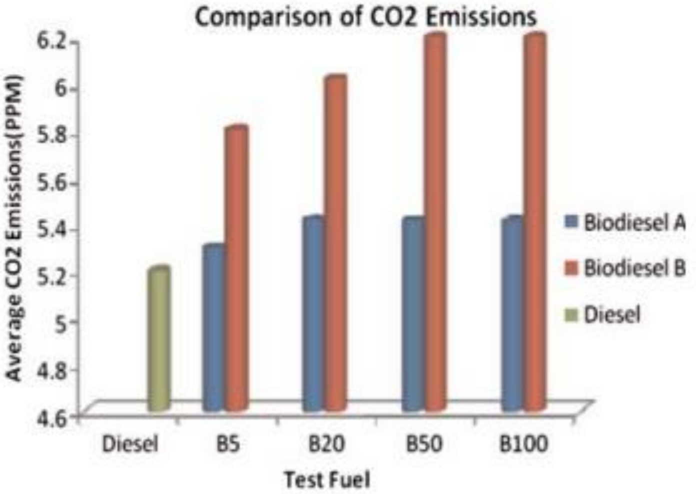

Figure 7. Comparison of carbon dioxide emissions

5. Summery:

- Biodiesel's lower energy content reduces performance (torque and power).
- It demonstrates a loss of power and torque with biodiesel.
- HC and CO2 emissions from both biodiesels grow as the quantity of biodiesel in the mix increases, while CO emission drops.
- Biodiesel B has a greater fuel consumption than Biodiesel A and a lower energy content. Fuels with lower energy content have greater fuel usage.
- Compared to Biodiesel B, Biodiesel A has fewer emissions and higher performance. NOx emission varies on biodiesel type, engine type, and test process. In this experiment, Biodiesel A has a falling trend with increasing blend ratio, but Biodiesel B has a rising tendency.
- Increasing the mix ratio of oxygenated biodiesel reduces CO emissions owing to full combustion in the diesel engine. Because biodiesel contains oxygen, it may be completely burned in a diesel engine.
- Increased density biodiesel should result in higher fuel usage.
- A biodiesel engine with a higher cetane number and lubricity is more efficient.
- Higher calorific value (energy content) biodiesel creates more power.
- This creates issues with fuel flow and ignition in engines, reducing power output.

6. CONCLUSIONS:

The research found that biodiesel is more eco-friendly than petroleum diesel due to lower CO and NOx emissions.Though biodiesel contains less energy than petroleum diesel, it performs worse. Biodiesel A (80% beef, pig, and sheep tallow, 20% waste cooking oil methyl ester) had lower exhaust emissions than Biodiesel B (80% chicken tallow, 30% waste cooking oil methyl ester). It was impossible to make solid conclusions regarding why emissions were greater for biodiesels without knowing more about their particular fuel qualities, such as final analysis. It is suggested that a follow-up research be conducted to evaluate how the differences in chemical characteristics effect performance and emissions. These data may then be sent into an engine simulation programme to analyse theoretical emissions. If the model is precise enough, the theoretical data might be compared to the empirical data from this research, providing greater insight into biodiesel's performance and emissions.

References:

1. C.L. Peterson, J.C. Thomson, J.S. Taberski, D.L. Reece, G. FleischmanLong range on road test with twenty percent rapeseed biodieselAppl. Eng. Agric., 15 (2) (1999), pp. 91-101
2. B.N. Kale, S.V. Prayagi, Performance Analysis of Cottonseed Oil Methyl Ester for Compression Ignition EnginesInt. J. Emerging Technol. Adv. Eng., 02 (8) (2012), pp. 117-120

3. I.M. Rizwanul, Fattah, H.H. Masjuki, M.A. Kalam, M. Mofijur, M.J. Abedin, Effect of antioxidant on the performance and emission characteristics of a diesel engine fueled with palm biodiesel blends,Energy Conversion Manage., 79 (2014), pp. 265-272
4. Pradhan A, Shrestha DS, McAloon A, et al. Energy Life-Cycle Assessment of Soybean Biodiesel. United States Department of Agriculture, Agricultural Economic Report, Number 845, 2009.
5. Biodiesel returns more energy to the earth. 2009. http://www. thebioenergysite.com/news/4781/biodiesel-returns-more-energy-to-theearth (viewed 22 October 2009).
6. National Biodiesel Board. What is biodiesel. 2008. http://www.biodiesel. org.au/biodieselfacts.htm (viewed 31 July 2008).
7. United States Environmental Protection Agency. A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions. EPA 420-P-02-01, EPA, 2002.
8. Wu F, Wang J, Wenmiao C, et al. A study on emission performance of a diesel engine fueled with five typical methyl ester biodiesels. Atmos Environ 2009;43:1481 –5.
9. Lin YC, Lee WJ, Wu TS, et al. Comparison of PAH and regulated harmful matter emissions from biodiesel blends and paraffinic fuel blends on engine accumulated mileage test. Fuel 2006, doi:10.1016/j.fuel.2006.04.023.
10. Saka S, Isayama Y. A new process for catalyst-free production of biodiesel using supercritical methyl acetate. Fuel 2009;88:1307 –13.
11. Eastop TD, McConkey A. Applied Thermodynamics for Engineering Thermodynamics, 5th edn. Longman Scientific & Technical, 1993.
12. Agency UE. A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions. U.S. Environmental Protection Agency, 2002.
13. Wyatt VT, Hess MA, Dunn RO, et al. Fuel properties and nitrogen oxide emission levels of biodiesel produced from animal fats. JAOCS 2005;82:585 –91