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RESEARCH ARTICLE

Performance and Emission Characterstics of Diesel Engine Using Milk Waste Water Bio-diesel

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Abstract: Due to increased usage of petroleum products, fossil fuels are getting exhausted. After discussions, scientists came to a conclusion that there should be an alternative fuel source which can be used instead of diesel. Through this experiment, the authors are going to investigate the possibilities of using milk waste water bio-diesel as an alternative source. The milk waste water methyl ester blends are added with fuels at ratio of 10% and 20% and a turbo charged diesel engine is used to test it. The engine is running under steady condition. The concentration of nitrogen oxide (NO_x), carbon monoxide (CO), total particulate matter (PM) and unburned hydro carbon are mainly observed in this experiment. From the recorded results, it is concluded that the milk waste water methyl ester (MWME) did not encounter with the engine thermal efficiency when comparing with the diesel engine. The outcomes of MWME upon CO and HC emissions were depended upon the load given to the engine. This resulted in poor breakup and evaporation properties. While comparing with soya bean bio-diesel, the milk waste water bio fuel emitted less NO_x. A same test with milk waste water with milk waste water and soya bean fuel was done with high and low load conditions to absorb the particulate matter emissions. The results exposed that at lower load conditions, the level of PM emission was very high for milk waste water bio-diesel blend when comparing with soyabean blends and the fossil diesel.

Keywords: Fossil diesel, Pollution, Nitrogen oxide, Biodiesel, Methyl ester, Particulate matter

1. Introduction

In this research, the alternative source for diesel which can produce high efficiency as well as less pollutions was discussed. Normal diesel produces very toxic pollutants which causes air pollution and green house effects. The newly introducing alternative fuels must reduce the emission of nitrogen oxide (NO_x) and particulate matter (PM) emission to reduce today's pollution and to meet the future pollution standards. Thus, the future era demands

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a good fuel alternative for diesel, which should meet all its applications with reduced pollutants emission [1]. Therefore, the bio-diesel plays a major role in the transportation system due to the depletion of the fossil fuel. Therefore, a physiochemical analysis was done on the bio-diesel to study the thermo physical properties and molecular structure of bio-diesel for perfect and improved engine performance and for reduced pollution [2]. The bio-diesel industry does not expand and few back pulled them and criticized them. Even though in the stage of high fuel price, no one is demanding for replacing the diesel with bio-diesel which will be economical to customers. Milk Waste Water, which is commonly called as the milk waste which is a non-edible crop extracted from milk poultry [3]. This oil plant can be grown anywhere and does not depend on climate as well as soil conditions. The oil can be processed from the MWME bean at very low production cost [4]. The 90% of the milk waste water contain, per mol of ricinoleic acid (12-hydroxy-9-cis-octadecenoic acid). The milk waste water contains long chain fatty acids which makes a double bond on its 12th carbon. When comparing with fossil diesel, the milk waste water bio-diesel has more polarity, which affects the engine heating [5]. Even though the milk waste water bio-diesel has advantages as well as disadvantages. It should be well inspected in all perspective before commercial recommendation. Very few researches have been done on milk waste water biodiesel and which has some contradictions [6].

During an experiment with milk waste water bio-diesel, the break specific volume increased to 3.3%, 7.2% on the blend upto B25. Not only that, the bio-diesel also produced much more unburned carbon monoxide and hydrocarbon emission when comparing with fossil diesel [7]. Major observations like particulate matter, fuel efficiency and nitrogen oxide effects were not observed. Another experiment was done like the same. The results exposed that there was an increase of 6.5% for B20 fuel blend, 14.2% for B10 fuel blend and 4.7% for B05 fuel blend when comparing with fossil diesel which resulted in better combustion, better lubricity as well as low friction losses [8]. In another experiment, with milk waste water bio-diesel blends of concentration B05, B10, B25, B50 and B100 was tested on a diesel engine [9]. The results exposed that the B25 blend of milk waste water bio-diesel is the best and suitable alternative for fossil diesel. The observations were reported a decrease of 1.5% in fuel conversion efficiency and 4.5% of the BCFC by using the milk waste water B25 bio-diesel fuel blend [10].

From the above experiments it is understood that, there should be further research done on milk waste water bio-diesel since there are only few researches done on it till date. Now in this research a set of steady load engine tests with the bio-diesel and the observations were recorded in the terms of pollutant emission, fuel consumption and thermodynamic efficiency.

2. Materials and Methods Used

In this experiment, along with the milk waste water bio-diesel, soya bean oil bio-diesel which has low viscosity was used to compare the results. As a base line fuel, ultra-low sulfur mineral diesel (11 ppm) and 20% of B20 blend and 10% of B10 blend was prepared. Through the process of homogeneous transesterification reaction, methyl esters were produced from milk waste water and soya bean oil. By using digital viscodensimeter, the values of kinetic viscosity and specific gravity were measured [11]. Under ASTM D93 standard, the flash point determination was done using a tanaka (APMY) apparatus and the Pensky-martens closed cup method and the results were recorded.

Table 1. Properties of Pure diesel and Blended biodiesel

Properties	Diesel	SOME	MWME
Kinematic viscosity [cSt @ 40°C]	2.51	4.1	4.3
Specific gravity [kg/m^3]	826.7	879.7	921.5
ester content (Monounsaturated) [% mol]	-	24.65	91.41
ester content (Polyunsaturated) [% mol]	-	54.61	6.9
Iodine value [gI2/100g]	-	120.4	81.3
Higher heating value [MJ/kg]	44.52	42.44	35.33
Cetane Number	47.7	51.1	49.9
boiling point[°C]	169.7	345.5	403.7
Flash point [°C]	63	174.5	271.3

Table 2. Specification of the test engine

Engine Specifications	
Type of the engine	4 stroke DI diesel engine
brake power in KW	83 (max)
brake torque in N.m	340 (max)
cylinders	6
Bore/Stroke ratio in m	0.101 m/0.118 m
Compression ratio	15.4:1
Type of injection	inline pump
opening pressure of the injector	290 bar

3. Dynamometric Bench Experiment

By using a MWM 229-T6, turbo charged direct injection diesel engine, the tests conducted in steady state. Three different loads to the break mean effective pressures (bmep) of 250 kPa, 500 kPa and 750 kPa at constant speed of 1800 rpm for testing the fuel. During the engine run, the minimum load given was 33%, then 66% and then 100%. The engine operation was controlled with an automated test bed to identify the emission parameter. All the data were collected with 10 minutes of engine run at steady state [12]. The calculated properties of diesel and biodiesel is shown in the Table 1 and all the results were triplicated and the specification of that engine is given in the Table 2. A servo actuator was linked to the fuel pump rack which controls the engine load and the dynamometer maintained the speed in constant. Air intake of the engine in different tests should be properly ensured for better NO_x measurements. The overall exhaust volume is measured with a mini-tunnel regulating at 1/100 which enclose with residue and soluble fraction, from the diluted exhaust gas at 50 °C with the use two filters particulate matter is possible to capture [13].

Table 3. Uncertainty values

Engine parameters	Uncertainty
Speed of the engine in rpm	± 4.6
Torque in N.M	± 1.16
Temperature of the intake air in deg cel	± 0.04
Pressure of the intake air in KPa	± 0.13
Coolant temperature in deg cel	± 0.36
Temperature of the Engine oil in deg cel	± 0.61
Temperature of the fuel in deg cel	± 0.14

The accumulation of individual sample with the improved mass by each filter through 10 minutes also concentration of pollutant were calculated, the heated lines and definite heated filter from the set of pollutant evaluator which is wiped out. On the other hand another sample is taken from the exhaust path and the models CAI 600 HFID of flame ionization evaluator were measured in the THC mode for the unburned hydrocarbons. In the chemiluminescence apparatus with NO_x/NO mode nitrogen oxides is recognized with a CAI 600 HCLD model, in the view to limit the concentration of unburned hydrocarbons from the biodiesel at 120 °C and the non-diffusion blooming method for CO and CO_2 bond with fuji ZPA evaluator the emission O_2 is completed by the paramagnetic method with measurement setup was shown in Figure 1. Uncertainty values are also calculated and shown in Table 3.

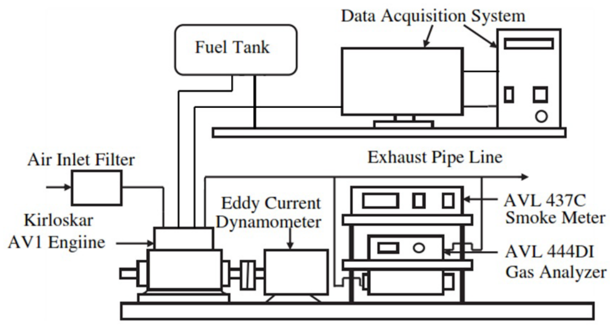


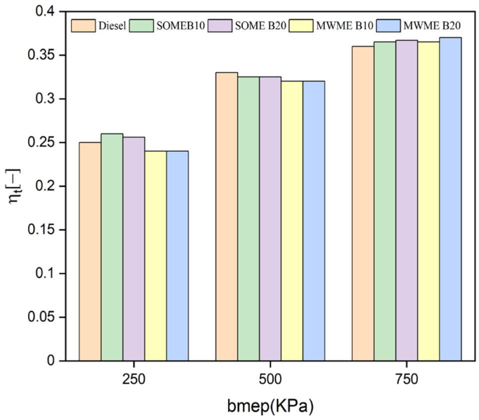
Figure 1. Schematic representation of the experimental setup.

Needle lift measurements and estimation from injection line pressure are the two specific process if the start of the injection angle was mutated with biodiesel blending which is detected by the process, while in the comparison of needle lift measurement is distant defined than the pressure line pressure but line pressure is prominent in the comparison which is studies based, at the existent of peak injection pressure sauter mean diameters (SMD) were calculated and theoretical injection spray diagnostic is conducted [14]. The calculation is based under the fuel line pressure and engine indicating data for sauter mean diameter (SMD) according to the procedures from the reference engine fuel conversion efficiency (η_t), brake specific consumption and specific pollutant emissions value were calculated [15].

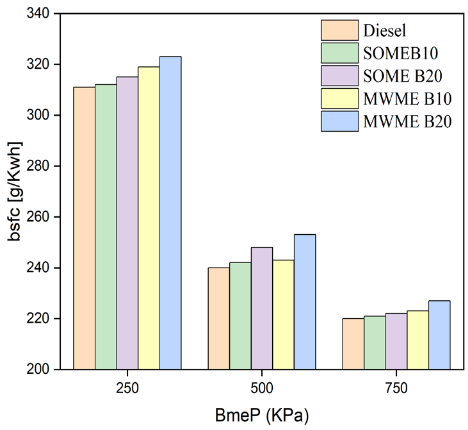
4. Results and Discussion

4.1 Engine Performance

The affinity to the mineral diesel which does not affect very much the engine thermal efficiency by using the biodiesel blends, it is extensively preferred. This trend was followed by the MWME biodiesel B10 and B20 fuel blends, whereas of their subsidiary spray relevant properties. At high load condition η_t data for the both MWME and soybean biodiesel is marginally efficiency is gained, η_t deviation between the tested fuels in the low and medium loads are not over the irrevocable margins which is shown in the Figure 2(a).



(a)



(b)

Figure 2. (a) Thermal Efficiency of the blended fuels; (b) Specific fuel consumption of the blended fuels

Brake specific fuel consumption increases due to the penalty force upon by every biodiesel blends into the fuel heat rate along with over and above the published studies are reporting about it, B10 and B20 fuel blends were recorded at its preeminent level of brake fuel consumption. Soybean correlate has a higher heat value than its milk waste water biodiesel, the milk waste water biodiesel is 11.3% and 4.6% denser and the part of this tendency can be retrieved in the volumetric terms than the diesel fuel and soybean biodiesel respectively which is eager to found out and shown in the Figure 2(b). Moreover, this was a predicted result where in the terms of engine performance fuel economy gains and in the hostile efficiency [16].

4.2 HC Emission

The tested fuels pinpoint that the precise unburned hydrocarbons were compressed with engine loads and fuel injection pressure is increasing. There is an even decreasing of HC due to addition of soybean biodiesel instead for diesel in all load condition for the fuel blends of the B10 and B20 were recorded on the average reduction of 18% and 21% respectively. The low sulphur diesel is from the soybean biodiesel which is integrated with the similar tendency was reported, blends B10 and B20 is affinity with the diesel and found out there is a decreasing of HC by 28% and 32%.

The presence of oxygen and fuel ignition quality is primary characteristics for the biodiesel which is usually considered to guide the HC emission with the sharp decreases. In the ignition site due to the decrease of HC emission while grant for the fuel oxygen in the respective site with that oxygenated fuel may enhance the ignition [17]. The fuel which having a high cetane number is the fact which was based under the second attribution like biodiesel, will tends for the ignition delay. During the process of ignition the amount of HC prone fuel has been mixed scanty than the flammability range which restricts the reduced ignition delay [18].

The result is noted by using diesel or soybean biodiesel blends that ramshackle with the engine load minimization, whereas that the HC emission of the MWME biodiesel blends also exhibit the resembling result to soybean at high load and poor result than diesel at low load. From Figure 3. Consideration of three fuels by the central of its cetane index number and 40% higher oxygen content in the milk waste water biodiesel with respect to the soybean biodiesel. The effect over the oxygen content under the dominance of cetane number is justified at the HC levels at bmep's of 500 kPa and 750 kPa. In order to demonstrate the observed results at 250 kPa which is characterized from the factor by its load dependence [19].

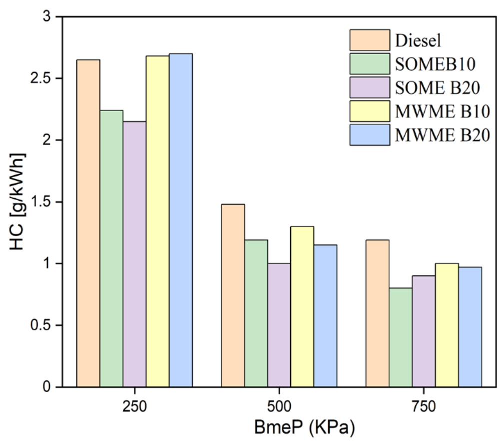


Figure 3. Emission of Hydrocarbon (HC)

In the milk waste water biodiesel can be associated to the outcast of the HC behaviour and complication involved into its atomization and subsequent evaporation, during apex injection pressure of about 380 bar is being measured as a fuel jet momentum is lessened at low engine loads, fuel atomization and vaporization emerge as critic in the divergence to the 750 bar is usually reached at high load conditions. The trait of the atomization process for the mean diameter is taken as a qualitative reference, the SMD is increaseed by 9.2 μm (ca. 40%) cause from the blend B20 while with the relation to the baseline diesel fuel there is SOME B20 to increase by 1.7 μm (8%) [20]. The constrain may add the complication to the consecutive droplet evaporation when the normal boiling point (401 °C) of the MWME bio-diesel.

4.3 CO Emissions

It was predicted from the prior consultation that the higher values of viscosity, surface tension and boiling temperature of the MWME fuel blends when compared to SOME blends it may had a percussion in their emissions, the emissions that CO and HC are mutually related and the product of incomplete fuel oxidation is carbon monoxide. From Figure 4, MWME B20 blend extrude more amount of carbon monoxide than the baseline fuels in all tested modes and CO effect is even more higher in the observation for HC which was as a MWME B20 blend. The fall off of CO emission at low engine load 10% is enough of MWME blending.

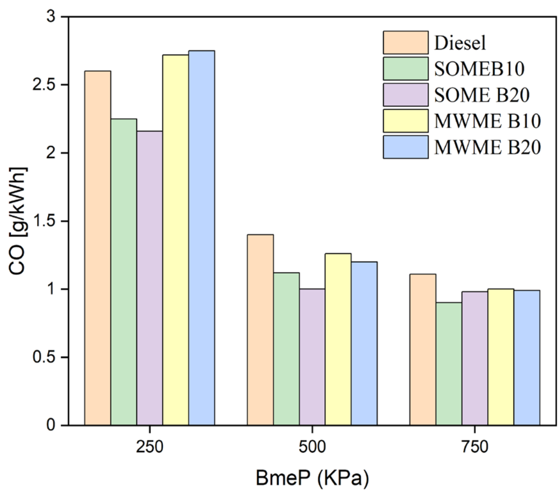


Figure 4. Emission of Carbon monoxide (CO)

The emissions of HC and CO levels are higher for soybean blends with the consideration of B20 biodiesel blends which was followed by the MWME and mineral diesel. The consecutive fade of CO emission by the blending MWME biodiesel into diesel fuel which is justified with some reference and the presence of the fuel oxygen is increased, besides the complication of the increased emission where the results pinpoint the soybean biodiesel chemical structure and MWME atomization [21]. The HC and CO emissions are mutually related which is about to decrease with rapeseed and low chain methyl ester taking account into the oxygen content as a positive effect and a boiling temperature as an adverse problem [22].

4.4 NOx Emissions

4.4.1 Injection Timing

The inconsistence of fuel abridge cause from the advance of injection time and more report demonstrate about the NO_x emission biodiesel mulct, by elevating the travel speed of the pulses that occurs not beyond the mechanical injection system which in the deem of advanced injection system. The values of fossil fuel is usually lower than the values of bulk modulus of biodiesel along with there is an increase in the degree of unsaturation which is another specific property, ignition temperature would extend in the advanced injection for the favourable ambience to NO_x formation which is shown in Figure 5.

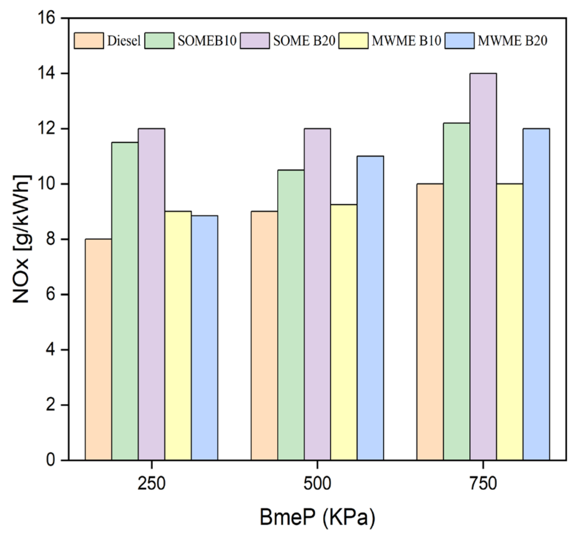


Figure 5. Emission of NOx

The respective data is obtained from the needle lift for the beef fat, MWME and soybean blends B20 the premium encoder is not feasible at any injection preferment for both MWME and soybean oil biodiesel blends the primary cause of NO_x is at tight injection as 0.1 degree extreme which is not valid [22]. In order to contribute the low iodine value (42 gI_2/100g) is delineated from the beef fat biodiesel, representation of MWME and biodiesel were dissipated about to 83 gI_2/100g and

121 gI_2/100g. The method of less fuel injection was guessed at from the injection foremost, the knowledge of injection line pressure is impressive to point the previous injection is mutually correlated to the biodiesel iodine number also found out the oppose termination in the attempt. Comparison takes over line pressure from the amplification of biodiesel that fasten the pressure complication which tends to cause of timing forward and provoked by the biodiesel.

4.4.2 Biodiesel Structure and Properties

The iodine value of each biodiesel combination is fixed and remains with emission were brings the possibility level higher for conversion into fuel, affinity of the biodiesel blends and fossil fuel with the extreme NO_x levels is observed. The MWME blends (IV=83.4) emitted less NO_x than soybean biodiesel blends (IV=121.6), complication of the atomization are about to diminishing the charge temperature at a particular test mode moderation of NO_x is very effective in a point, the rid of MWME B10 at bmep = 250 kPa generating more NO_x was observed under the concentration effect.

Under the rule of C=C double bond which may leads to depress overall rate reaction so that there must be an increase of C=C double bonds and overall ignition rate while at high temperature, kinetics of biodiesel combustion also plays a vital role in the iodine value moreover, its mutually correlated with the injection development. Due to formation of nitrous oxides cetane number act as a key specification by the three layer effects nitrogen oxides is formed and restrained which was proposed by the authors. According to their results of NO_x formation in a radiative heat transfer plays as a tertiary role, because the adiabatic flame temperature is appeared under the effect of ignition lag as a secondary role, by modifying the heat release history and the ignition stoichiometry along with CN and ignition lag plays a primary role.

The results obtained from the MWME and soybean biodiesel B20 blend demonstrate about the quick combustion at the extreme temperature with the effect of increased flame, it may leads to fail the quality at the integrated levels of blends B10 and B20 when the CN is associate with diesel fuel (+0.2% to SOME and +4.4% to MWME) both a biodiesel have a slight diffusion. The heat value and flame temperature are about to down with knowledge because of the higher oxygen content of MWME while comparing to soybean, prominence of this effect has a higher unsaturation degree of soybean biodiesel. The ignition is related to fossil fuel through the impact of double bond whereas, from the slight effect range of MWME increases about to 21.3% at B25 fuel blending.

4.5 PM Emissions

All engine load modes of soybean biodiesel blends which may scaled down the impure when combine with to the diesel due to reserved oxygen vacancy the relative weight of contaminant is expanded at low load mode there is a small fall of MWME. Reporting the coinciding execution at mean and high levels of load which is compelling to find out, the noteworthy thing is at a break mean effective pressure of 750 kPa only is about to consecutive decrease of particulate matter with biodiesel blend.

Simultaneously, the residue formation is decreased and oxidation is increased by the consideration of biodiesel, the result obtained here for the soybean biodiesel blends during the conversion of diesel fuel from the biodiesel blending typically which is about to diminish the total particulate matter emissions.

During fuel thermal atomization the mutual relation of residue emission with the number of double bonds present in the biodiesel structure by means of ethene and ethyne is traced. Consideration of other factor from the gathered result for the discussion, the related properties are about to extreme were found out with the disparage spray by the particulate matter. The formation of hydrocarbons can strengthen the possibility of residue or disrupt the matters, fuel saturate fraction and particulate matter SOF is in an ingrained unswerving relationship. The contain of small fuel droplets from the biodiesel combustion with the composed of high cetane number of mode particles whereas, boiling points of biodiesel molecules is mutually related with the concentration of nuclear mode particle in the exhaust gas.

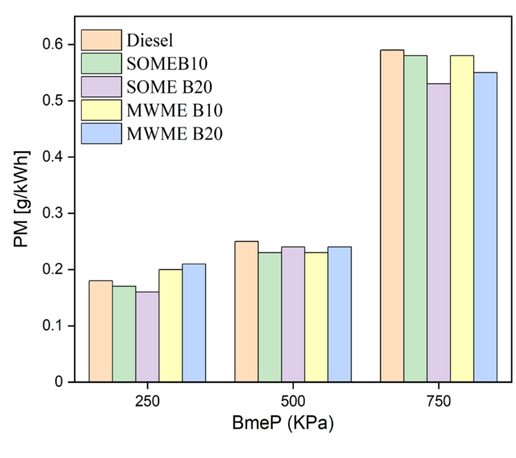


Figure 6. Emission of particulate Matters (PM)

The higher oxygen content and lower saturation degree are the two positive manner of MWME biodiesel when considering the soybean biodiesel blends as a reference, in the early work no consign is about the particulate matter effects of MWME biodiesel were known at the middle of the high engine loads it seems that deal among the aspects carried out the similar results to MWME and soybean biodiesel blends. On the other hand, affliction of HC and CO emissions by the same boiling point and viscosity factor may tend to increase the residue nucleation and soluble factor. From Figure 6 MWME B10 and B20 blends at low mode the dissipation related complication is possible also it acquires the higher levels of particulate matter than the reference diesel fuel and soybean blends. In the test mode MWME blends B10 and B20 is tested were B20 provide the expected result because MWME B20 discharge less NO_x than the MWME B10 which propose the decrement of charge temperature.

5. Conclusions

Based on the above research it was concluded that milk waste water biodiesel provided optimum efficiency and the below conclusion's were obtained.

1) The impact is not possible on engine thermal efficiency with affiliation to diesel fuel by the blends B10 and B20 of the milk waste water biodiesel even supposing of its inconvenient spray related properties.

2) While contrary at low engine load result is not affirmative but at high and mid loads the result is not same to MWME biodiesel blends. The covenant between the fuel oxygen content, poor break and evaporation properties.

3) In the need of advance fuel injection for the engine did not use of MWME biodiesel blending into diesel fuel also give same result for soybean biodiesel.

4) Biodiesel iodine value was mutually related to the retribution of nitrous oxide both MWME and soybean biodiesel blending into fossil fuel consecutively NO_x emission is increased but MWME biodiesel emitted less NO_x than the soybean.

5) The affinity to the soybean and MWME biodiesel were reduced the flame temperature and NO_x emission but the values are similar for the cetane index of tested fuels

6) At all engine load modes soybean biodiesel with diesel fuel reduced the particulates.

7) The particulate matter emissions of MWME blends did not affect the improved oxygen content with soybean biodiesel.

8) During at mid and high loads modes of engine a similar decrease is occurred in particulate matter emission with relation to the fossil diesel, MWME biodiesel blends emitted higher levels of PM than soybean blends and reference fuel while at low load modes.

Conflict of Interest

There is no conflict of interest.

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