Effect of antioxidant on performance and emission characteristics of diesel engine fuelled with diesel-palm biodiesel blends -A review study

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ABSTRACT

In conventional CI engine diesel is used as a fuel which provides better power, efficiency and basic specific fuel consumption. But it increases the CO_2, CO, HC, SOX and NOx emission. Which affect the environment and human health. It causes global warming and greenhouse effect and sometimes acid rain too. Also diesel fuel is nonrenewable energy resources and increases our dependency for importing fuel on other country.
Due to depleting the fossil fuel and increasing effect of environment pollution from this fuel demands an ecofriendly alternative which can be used in diesel engine without any major modification.
This study presents a detailed analysis of the effect of antioxidant on performance and emission characteristics of diesel engine fuelled with diesel-palm biodiesel blends. It is observed that using palm biodiesel in diesel engine emits lower CO and HC and emits higher NOx. Higher level of NOx emission can be reduced by adding phenol group antioxidant in biodiesel and its blend.

Keyword - *Palm, biodiesel, emissions, fuel consumption, antioxidant, NOx reduction*

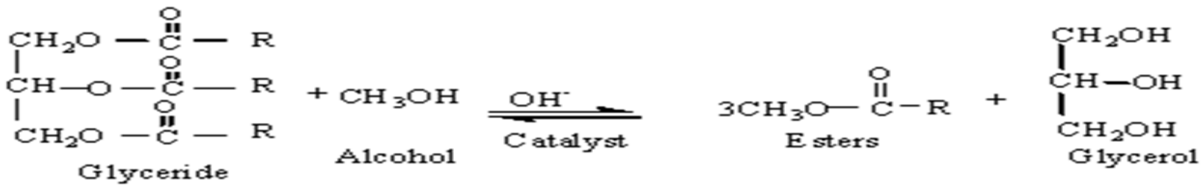
1. Introduction

From previous studies, Straight vegetable oils used in engine lead to various problems like fuel filter clocking, poor atomization and incomplete combustion because it is highly viscous, high density and poor non volatility[1][2][7]. In order to reduce the viscosity of the straight vegetable oil the following four techniques are adopted; namely heating/pyrolysis, dilution/blending, micro-emulsion and transesterification[1][8]. Among all these techniques the transesterification is an extensive, convenient and most promising method for reduction of viscosity and density of the straight vegetable oils[1][7][8]. However, this adds extra cost of processing because of the transesterification reaction involving chemical and process heat inputs[1][7][8].

1.1 Biodiesel production

The transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol[1][7][8]. Almost all biodiesel is produced in a similar chemical process using base catalyzed transesterification as it is the most economical process, requiring only low temperatures and pressures while producing a 98% conversion yield[1][7][8].
During the transesterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide[1][7][8]. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel, and crude glycerol[1][7][8]. In most production, methanol or ethanol is the alcohol used (methanol produces methyl esters, ethanol produces ethyl esters) and is base catalyzed by either potassium or sodium

hydroxide. Potassium hydroxide has been found more suitable for the ethyl ester biodiesel production, but either base can be used for methyl ester production[1][7][8].
The figure below shows the chemical process for methyl ester biodiesel. The reaction between the fat or oil and the alcohol is a reversible reaction, so the alcohol must be added in excess to drive the reaction towards the right and ensure complete conversion[1][7][8].



1.2 Performance and emission analysis of palm biodiesel and it's blend

Literature reviews shows that palm biodiesel have almost similar property compared to diesel fuels so palm biodiesel and it's blend can be directly use in diesel engine without any modification[2][9][10]. Performance analysis shows that Thermal efficiency of palm biodiesel and oil blends with diesel fuel was lower compared to diesel fuel and specific fuel consumptions were found to be higher[2][9][10]. Air- fuel ratios for diesel-palm biodiesel blends were lower than diesel fuel[2][9][10]. Exhaust emissions of CO and HC were reduced relative to conventional diesel fuel[2][9][10]. NOX emissions increased relative to conventional diesel[2][9][10].

1.3 Effect of antioxidant

It has been observed that biodiesel have poor oxidation stability[4][12]. Oxidation can alter the physical and chemical properties of fuel e.g., it can cause acidity and increasing viscosity due to formation of insoluble gums that can plug fuel filters[4][12]. The use of antioxidant additives can help slow the degradation process and improve fuel stability up to a point[4]. By using the antioxidant it is possible to store biodiesel for longer time. Also it have been observed that addition of antioxidant can reduce the higher level of NOx emission caused by biodiesel[6]. Synthetic antioxidants are more effective compared to natural antioxidants(vitamin E, α-tocopherol and β-carotene). Synthetic phenolic antioxidants namely BHA(Butylated hydroxyanisole), BHT(Butylated hydroxytoluene) and TBHQ(tert-Butylhydroquinone) gives better oxidation stability and reduce NOx emission in biodiesel[4].

2. Literature Survey

F. Halek, A. Kavousi, and M. Banifatemi study the feasibility of biodiesel as an Alternative Fuel for Diesel Engines. The biodiesel can be produced from the vegetable oils or animal fats by transesterification process. It was observed that Biodiesel is recommended to use as a fuel in diesel engine because it is a renewable, domestic resource with an environmentally friendly emission profile and is readily biodegradable. Biodiesel is cheaper fuel for consumer, provide more energy security & diversified sources, gives higher farm incomes & rural employment, gives significant reduction in carbon emission, lowers imports & energy prices.

M.S. Gad, R. El-Araby, K.A. Abed investigated the Performance and emissions characteristics of C.I. engine fueled with palm oil/palm oil methyl ester blended with diesel fuel. The experiments were carried out on a single cylinder, four stroke, air cooled, direct injection, naturally aspirated, constant compression ratio, diesel engine at National Research Centre, Engine Research lab., Egypt.
It is observed that in case of biodiesel, palm oil and its blends with diesel fuel, diesel engine consumes more fuel than diesel fuel to develop the same power. Specific fuel consumption values for diesel, B20, B100 and PO20 are 0.28, 0.316, 0.346 and 0.325 kg/kW.hr, respectively at full load. Thermal efficiency is slightly lower for palm oil blends PO20, B20 and B100 compared to diesel fuel at all engine loads. Thermal efficiencies for diesel, biodiesel blend B20, B100 and PO20 fuels are 28.7, 27.7and 24.7 and 26.8%, respectively at full load. There is an increase in exhaust gas temperature with increase of engine load for all the blends and diesel. The heat loss in exhaust gases increased with the increase in engine load. Exhaust gas temperature values are observed for diesel, B20, B100 and PO20 are 302, 312, 371 and 322 C, respectively at full load.

CO emissions decreased with increase in engine brake power. The decreasing carbon monoxide emission for biodiesel blends was due to more oxygen molecules and lower carbon content in biodiesel blends as compared to conventional diesel fuel. For diesel, B20, B100 and PO20 the values of CO emission are 0.1, 0.062, 0.054 and 0.075% respectively, at full load operations. Unburnt hydrocarbon(HC) emission is lower at engine part load and increase as higher loads. This is due to the presence of fuel rich mixture and lack of oxygen. There is slightly reduction in HC emissions for palm biodiesel blends B20 and B100 with diesel fuel at all engine loads with respect to diesel fuel. HC emissions increased for PO20 at all engine loads compared to diesel fuel due to higher viscosity of palm oil. The values of HC emission for, B20, B100, PO20 and diesel fuel are 39, 30, 48 and 45 ppm, respectively at full load operation. NOx emissions increased for all the test fuels with the increase in engine load due to increase in the quantity of fuel burned and the amount of cylinder temperature which is responsible for thermal NOx formation. The higher NOx emission for B20, B100 and PO20 was due to more oxygen content compared to diesel fuel. The values of NOx emission for diesel, B20, B100 and PO20 are 174, 190, 285 and 301 ppm respectively, at full load operation.

S. Nagaraja, K. Sooryaprakash, R. Sudhakaran investigate the effect of compression ratio on the performance and emission characteristics of variable compression ratio engine fueled with preheated palm oil - diesel blends at full load condition it is observed that by increasing compression ratio, the engine performances are varied and it is compared with standard diesel. The following results are presented in variable compression ratio engine with functions of fuel blends, load, and compression ratio.
The brake power of PO20 is higher than that of standard diesel and other tested fuels at higher compression ratio and full load condition. Observation of this study indicate that while increasing the compression ratio of the engine the mechanical efficiency was increased at full load condition. This may offers better thermal efficiency of the engine. The indicated mean effective pressure for diesel is higher than other tested fuels from lower compression ratio to higher compression ratio. The exhaust gas temperature of the tested fuels were found lower than diesel at higher compression ratio and full load. There is a significant reduction in CO and unburned hydrocarbon emission for all blends of preheated palm oil at higher compression ratio and full load. Also the CO2 emission level was higher than that of diesel for all other tested fuels from lower compression ratio to higher compression ratio.

Yung Chee Liang, Choo Yuen May, Cheng Sit Foon study, The effect of natural and synthetic antioxidants on the oxidative stability of palm diesel. The oxidative stability of crude palm oil methyl esters (CPOME) and distilled palm oil methyl esters (DPOME) were investigated using Rancimat test (EN 14112) as recommended in the EN 14214. Study on the effect of antioxidants on DPOME was also conducted.
Rancimat test shows that CPOME exhibit much better oxidative stability (RIP >25 h) than DPOME (RIP about 3.5 h). There was same properties noted between the two samples except the CPOME contains 644 ppm of vitamin E (a-tocopherol, 119 ppm; a-tocotrienol, 113 ppm; g-tocotrienol, 352 ppm; d-tocotrienol, 70 ppm) and 711 ppm b-carotene while the DPOME contains practically none (less than 50 ppm). Vitamin E and b-carotene are known as natural antioxidant. They both are responsible for contribute good oxidative stability of CPOME. As a result, no antioxidant was needed when using CPOME as diesel substitute.
On the other hand, DPOME does not meet the oxidative stability specification of the aforementioned standard. Thus, an antioxidant must be added to enhance their RIP. The result shows that approximately 0.1% of a-T required to meet the European biodiesel specification in terms of oxidative stability of 6 h. Only 50 ppm of BHT was needed to enhance the RIP to above 6 h. The RIP of DPOME was further increased linearly to 7.75, 13.10 and 16.60 h with increasing dosage to 100, 500 ppm and finally, 1000 ppm. A dosage of 50 ppm of TBHQ improved the RIP of DPOME by more than 5 h, from 3.52 to 8.85 h. RIP of 12.1 and 30.2 h were recorded when 100 and 500 ppm of TBHQ were added, respectively. Using dosage of 1000 ppm and above, DPOME became stable against oxidation with RIP greater than 48 h.

M. M. Rashed, H. H. Masjuki, M. A. Kalam study on the improvement of oxidation stability and NOx emission levels by antioxidant addition to biodiesel blends in a light duty diesel engine. MB20 (20% Moringa oil methyl ester and 80% diesel fuel blend) was mixed with three synthetic antioxidants, N,N0 -diphenyl-1,4-phenylenediamine (DPPD), N-phenyl-1,4-phenylenediamine (NPPD) and 2-ethylhexyl nitrate (EHN), at a concentration of 1000 ppm. The effects of these antioxidants on the oxidation stability as well as on the exhaust emission and performance on a single cylinder diesel engine fueled with biodiesel were analyzed.

MB20 biodiesel shows higher BSFC for all speeds throughout the experiment. The mean BSFC values are 261.42, 291.39, 283.57, 278.47 and 280.49 g kW h1 for pure diesel, MB20, MB20 + NPPD, MB20 + DPPD and MB20 +

EHN, respectively. From this calculated data, we noted that the mean BSFC of MB20 is 11% higher than that of pure diesel because of low biodiesel heating. By contrast, the addition of NPPD, DPPD and EHN with MB20 shows an average reduction of 2.68%, 4.44% and 3.76% BSFC compared with MB20.
BTE fluctuates with varied speed for all the tested blends. The maximum value of BTE is detected at 1800 rpm. The maximum values of BTE at this speed are 33.05%, 30.26%, 31.48%, 32.10% and 31.87% for B0, MB20, MB20 + NPPD, MB20 + DPPD and MB20 + EHN, respectively. Throughout all speeds tested, MB20 shows the lowest BTE and pure diesel displays the highest BTE. However, the mean BTE values for all tested blends are 31.03%, 28.6%, 29.46%, 30.02% and 29.81% for B0, MB20, MB20 + NPPD, MB20 + DPPD and MB20 + EHN, respectively. Hence, pure diesel produced 7.8%, 5.05%, 3.25% and 3.90%% higher BTE compared with MB20, MB20 + DPPD, MB20 + NPPD and MB20 + EHN, respectively.
Hence, it is observed that the presence of 1000 ppm DPPD, NPPD and EHN antioxidants in biodiesel could significantly decrease NOx. NOx levels linearly increase throughout the experiment. Therefore, pure biodiesel blends (MB20) clearly produce higher NOx contents compared with other blends. By adding antioxidants (DPPD, NPPD and EHN) to MB20, NOx emission comparatively decreases. The average NOx emissions are 609.57, 678.5, 638.49, 618.5 and 628.51 ppm for B0, MB20, MB20 + NPPD, MB20 + DPPD and MB 20 + EHN, respectively. Moreover, the average increase in NOx emission was 11.31%, 4.74%, 1.46% and 3.10% compared with that of B0.
HC emission gradually decreases with increasing speed. The maximum and minimum HC emissions are 1200 and 2400 rpm, respectively. Notably, the mean reduction values of HC emissions are 21.06%, 12.75%, 16.90% and 14.83 for MB20, MB20 + NPPD and MB20 + DPPD, respectively, compared with that for diesel. The average increases in HC in biodiesel added with NPPD, DPPD and EHN are 10.52%, 5.26% and 7.89%, respectively, compared with MB20.
CO emissions decrease adequately in all of the blends compared with pure diesel. The maximum CO emission was found in pure diesel. The mean decreases in CO emission are 27.1%, 13.16%, 23.43% and 20.75% for MB20, MB20 + NPPD, MB20 + DPPD and MB20 + EHN, respectively, compared with pure diesel. However, addition of 1000 ppm DPPD, NPPD and EHN antioxidants to biodiesel adequately enhances CO emission. Average increases in CO upon the addition of AO (NPPD, DPPD and EHN) are 18.96%, 4.89% and 8.56% compared with that of MB20, respectively. The amount of CO emission remains less upon the addition of antioxidants in biodiesel compared with that in pure diesel.

S.M. Palash , M.A. Kalam, H.H. Masjuki conducted an experimental study on a four-cylinder diesel engine to evaluate the performance and emission characteristics of Jatropha biodiesel blends (JB5, JB10, JB15 and JB20) with and without the addition of N,N0 -diphenyl- 1,4-phenylenediamine (DPPD) antioxidant. It was observed that the engine performance was reduced with and without the addition of DPPD additive in Jatropha biodiesel blends compared to diesel.
The addition of 0.15% DPPD in all Jatropha biodiesel blends reduces the NO emissions significantly. With the addition of DPPD, the average reduction in NO emissions for JB5DPPD.15, JB10DPPD.15, JB15DPPD.15 and JB20DPPD.15 were 8.03%, 3.503%, 13.65% and 16.54%, respectively, compared to the respective biodiesel blends without additive. The addition of DPPD antioxidant additive in tested Jatropha biodiesel blends increased the CO and HC emissions slightly. However, in comparison to diesel, these values remain lower.

3. CONCLUSIONS

Following conclusion can be drawn from the literature-

- It is observed that biodiesel is better alternative option to conserve the amount of fossil fuel.
- It is observed that Biodiesel decrease CO and HC emission but increase NOx emission compared to diesel fuel.
- It is observed that biodiesel have poor oxidation and storage stability.
- It is also observed performance and emissions characteristics of a diesel engine using palm oil methyl ester blends up to 20% with diesel fuel are reasonable.
- It is observed that variable compression ratio engine gives better performance and emission characteristics at higher compression ratio and full load condition.
- It is observed that addition of antioxidant in biodiesel increase long term storage and oxidation stability and reduce the NOx emission in biodiesel.
- It is observed that Synthetic antioxidants are more effective compared to natural antioxidant.

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