International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 02 | February - 2024 SJIF Rating: 8.176 ISSN: 2582-3930

A Review on Neem Oil as a Biodiesel and Its Effects on Engine Performance and Exhaust Emission

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Abstract - An increase in industrialization and mechanization leads to an increase in energy demands. Fossil fuels such as petroleum are the major sources of this energy. However, these fuels cause air pollution due to the emission of greenhouse gases. Therefore, raising a need for an alternative fuel that is ecofriendly. Biodiesel has been regarded as a substitute since it is friendly to the environment and it does not cause air pollution. The main methods applied in the production of biodiesel include transesterification, direct blending and use, and thermal cracking or pyrolysis together with micro-emulsions. Currently, researchers, policymakers, and investors have been persuaded to think of a fuel that will substitute fossil fuels. Therefore, this review paper addresses factors affecting production, the method used in producing this biodiesel, and the effects of biodiesel on the performance of the engine and emission of exhaust gases.

Key Words**:** Bio Diesel, VCR, Blending

1. INTRODUCTION

The major sources of non-renewable energy are Fossil fuels. Due to the increase in the vehicles which are operating daily as well as the upsurge of the number of industries, energy demands have also gone very high. The main sources of energy include coal, natural gas, and nuclear, and petroleum among others. Petroleum-based fuels such as petroleum diesel lead to pollution of the atmosphere since it emits several greenhouse gases when it's heated [1].

The majority of the energy demand of the world is met by burning fossil fuels. The transport system is a key factor for developing countries like India to social, regional, and economic cohesion, including the development of rural areas. In India vehicles owned per 1000 people increased from 7.5 in the year 2000 to 17.7 in 2010 which gave rise to vehicle fleet circulation and crude oil consumption as well[2]. During FY 2017-18, the consumption of petroleum products in India was 206.17 MMT with a growth of 5.95% as compared to the consumption of 194.60 MMT during FY 2016-17[3]. A diesel engine is a major tool in the day-to-day life of modern society. It powers much of our land and sea transport, provides electrical power, and is used for many farming, construction, and industrial activities. Figure 1 shows historic and future diesel fuel consumption data for India.

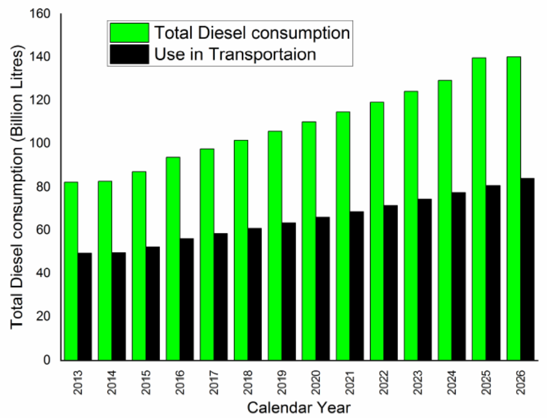

Figure 1Historic and future diesel fuel consumption data

Thus, creating a need for an alternative fuel that is more nature friendly and does not contain air contaminants. Vegetable oils such as the one extracted from Neem seeds are considered to be a good alternative since they are readily available in rural areas.

Biodiesel is a type of fuel that is produced through a chemical reaction of alcohol and vegetable oil. It's is defined as long-chain fatty acids monoalkyl esters that originate from oils from plants and animal fats. It is regarded as a potential substitute for oil in diesel engines due to its benefits compared to fossil fuels. These benefits include its Environmental friendliness, quick utilization of Carbon dioxide (CO2), nontoxicity, and biodegradability [2]. Neem seeds are an abundant source of biomass and are highly available in the United Arab Emirates. They contain a good amount of oil which can be extracted very easily and therefore it can be used as biodiesel [3]

The three major processes of obtaining biodiesel from these vegetable oils include catalytic cracking, trans-esterification, and direct blending. Parameters that are likely to affect the production of biodiesel include time, catalyst effect, the ratio of moles as well as the temperature of the reaction [4].

Triglycerides are the main components of vegetable oils and animal fats. The process of biodiesel production from these oils involves the reaction of triglycerides with alcohol to form an ester and alcohol. Biodiesel is considered to be safer to handle compared to petroleum diesel since its less volatile due to its relatively high flash point. It also has lubricating properties thus reducing the wearing out of engines thus engines have longer operational life [1]

Biodiesel usage in engines has shown better performance compared to petroleum diesel whereas exhaust emission of gases such as carbon monoxide and hydrocarbon has been found to reduce due to oxygen content in biodiesel [5]. Therefore, this paper reviews the different processes of production of biodiesel from neem oil, factors affecting the production, and its effects on the performance of engine and emission of exhaust gases.

2. Literature review

Effect of Catalysts & Blends

Saima Noreen et. al. [1] had done research on eco-benign approach to produce biodiesel from neem oil using heterogeneous nano-catalysts and process optimization and result revealed that the Fe, Ni and Cu doped ZnO catalysts are promising heterogeneous catalysts for transesterification of oil to biodiesel under mild reaction conditions.

Uday Bhan et. al. [2] had done research on effect of different loads on the friction and wear characteristics of material lubricated with neem oil and found that the 10% blend produces better results with comparison to other blends. Minimum wear was also obtained at 10% blend.

Olayomi A. Falowo et. al. [3] had done research on Sustainable biodiesel synthesis from Honne-Rubber-Neem oil blend with a novel mesoporous base catalyst synthesized from a mixture of three agrowastes and concluded that the ash derived from combination of the biomass wastes provided a catalyst which consists all necessary catalytic ingredients in their relative abundance. The calcined CPK consists of 47.67% of potassium, 5.56% calcium and 4.21% magnesium attesting to its heterogenous status. The physisorption isotherms reveals that it was dominantly mesoporous in structure and made up of nanoparticles. A maximum of 98.45 wt.% biodiesel was obtained from a MeOH:oil blend of 12:1.

Mayank Chhabra et. al.[4] had done research on optimization of the dual stage procedure of biodiesel synthesis from Neem oil using RSM based Box Behnken design and concluded that the optimal process variables for esterification was pronounced as alcohol to oil molar ratio of 7.4:1, 0.89 wt% of H2SO4 catalyst, reaction temperature of 41°C and reaction duration of 88 minutes yielding Neem oil with optimum FFA value of 1.91% and the predicted FFA value was 1.73%.

Devaraj Rangabashiam et. al.[5] had done research on performance, emission, and combustion analysis on diesel engine fueled with blends of neem biodiesel/diesel/ additives and concluded that adding 10% Volume of

Pentanol and DMC lowers the CO emission of NBD50D50 by 4.9% and 7.4% at all loads. In addition, 3.1% and 4.7% reduction in HC emissions were observed by blending 10% of DMC and Pentanol to base fuel in that order.

Mamta Mahara et. al.[6] had done research on tribological analysis of the neem oil during the addition of SiO2 nanoparticles at different loads and concluded that the minimum coefficient of friction was obtained when nanoparticles are added up to 0.3 percent. During higher amount of nanoparticles addition, more wear of the disc occurs. At 0.3 percentage of nanoparticles, improved results in terms of wear of the parts have been observed with comparison to the raw neem oil.

T. M. Yunus Khan [7] had done research on Direct Transesterification for Biodiesel Production and Testing the Engine for Performance and Emissions Run on Biodiesel-Diesel-Nano Blends and concluded that higher concentrated B20-nano blends of Neem (NOME20GO105) and Karanja (KOME20GO105) resulted in 31 and 30.9% of brake thermal efficiency, respectively, compared with diesel of 32.5%. The brake-specific fuel consumption (BSFC) was reduced by 10 and 11% for NOME20GO105 and KOME20GO105, respectively, compared to their respective B20 blends. Similarly, carbon monoxide (CO) was reduced significantly by 27 and 29% for NOME20GO105 and KOME20GO105, respectively.

Devarajan et. al. [8] had done experiment on experimental investigation on the effect of compression ratio over emission and performance characteristics of the diesel engine using ternary blends and concluded that a higher compression ratio is useful for minimizing nitrogen oxide emission, while a lower compression ratio is useful for minimizing carbon monoxide emission. CR16 works effectively with a higher proportion of diethyl ether (2.4 and 3.2%) and provides better results for minimizing emissions with improved performance.

Production Process

Jayashri et..al.[9] utilized biofuel from two different production process: esterification called ethyl esters and transesterification called methyl ester. They found that fuel is rather viscous compared to diesel. Chemically is equivalent to fatty acid methyl esters or ethyl esters, produced out of triacylglycerol (triglycerides) via transesterification or out of fatty acids via esterification. Transesterification (alcoholysis) is a reversible reaction in which one ester is converted into another by interchange of ester groups. In the reaction one mole of triglyceride oils contained in vegetable oils, animal fats, or recycled greases, reacts with three moles of alcohol to form one mole of glycerol (glycerine) and three moles of the fatty acid alkyl ester (biodiesel). In order to shift the equilibrium to the right, an alcohol, typically methanol is added in an excess over the stoichiometric amount, but ethanol can also be use.

Nair et. al. [10] The two main products, glycerol and fatty acid methyl/ ethyl esters (FAME/FAEE), are hardly miscible and thus form separated phases: un upper ester phase and a lower glycerol phase. After transesterification the properties of crude vegetable oil like density, viscosity, cetane number, calorific value, vaporization rate, and molecular weight are improved. The representation of transesterification chemical reaction is shown in equation 2.1.Triglycerides called as vegetable oil and R1, R2 and R3 represents the fatty acid.

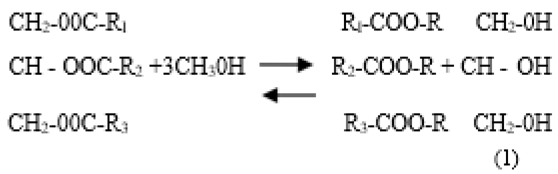

Figure 2 Esterification process

Atul Dhar et. al[11] investigated performance of CI engine using non edible oil and blend of oil with diesel produced from neem.A wide range of engine loads and volumetric blends of 5% neem biodiesel and 95% diesel, 10% neem biodiesel and 90% diesel, 20% neem biodiesel and 80% diesel, 50% neem biodiesel and 50% diesel are used for performance measurement of vertical, 4 stroke, single cylinder, constant speed, direct injection, water cooled, compression ignition engine of Kirloskar oil engine model no. DM-10.

Effect on Engine Performance

Shivalakshmi et al[12] investigated the performance and combustion characteristics of Kirloskar made, single cylinder, naturally aspirated, water cooled, direct injection diesel engine running on diesel, volumetric blends of 10% neem biodiesel and 90% diesel, 30% neem biodiesel and 70% diesel, 40% neem biodiesel and 60% diesel, 50% neem biodiesel and 50% diesel.

Duriraj et. al[13] evaluated the performance and emission characteristics of C I engine using diesel, 10% neem biodiesel and 90% diesel, 20% neem biodiesel and 80% diesel, 30% neem biodiesel and 70% diesel. The following performance and emission parameters investigated.

Vishvanathan et. al[14] reported that brake thermal efficiency was highest among all test fuels. All blends showed higher brake thermal efficiency than mineral diesel. Author found 20% efficiency with mineral diesel, 23% efficiency with pure biodiesel of 100% blend, which is 15% higher. They attributed this increase in brake thermal efficiency is due to presence of oxygen in the biodiesel molecules which improves the combustion efficiency.

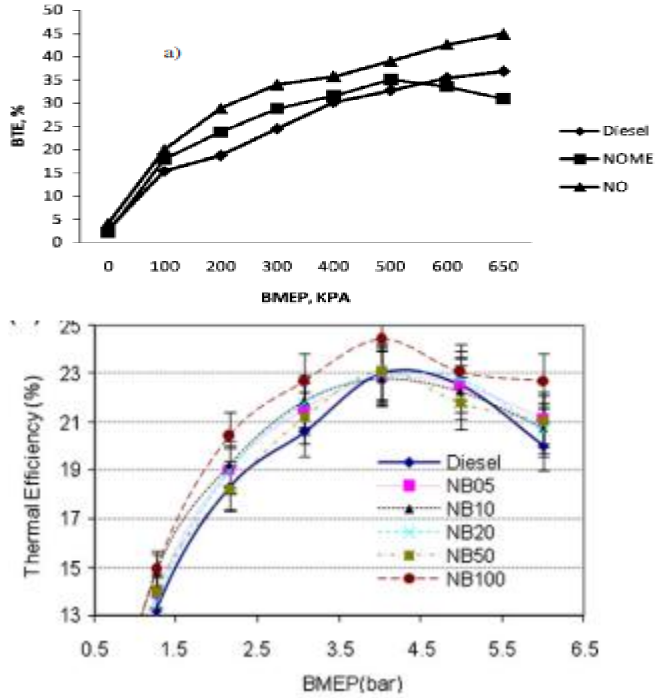

Figure 3 Thermal efficiency vs BMEP

As shown in figure 3, it indicates that neem oil blend pure shows more brake thermal efficiency as compare to neem oil methyl easter and pure diesel. Whereas, second figure shows that neem oil blend 100% shows highest thermal efficiency. So it can be clearly seen that as neem oil blending proportion increases it increase thermal efficiency.

Karthikeyan et al[15] observed that the brake thermal efficiency of blends 10% neem biodiesel and 90% diesel, 20% neem biodiesel and 80% diesel are almost very close to brake thermal efficiency of diesel. Brake thermal efficiency found 24.7% brake thermal efficiency by using pure diesel while 25.1% brake thermal efficiency by using30% neem biodiesel and 70% diesel, which is 1.63 % higher for blend 30% neem biodiesel and 70% diesel than pure diesel. They attributed this due to presence of increased amount of oxygen in respective fuels, which might have resulted in its improved combustion as compared to pure diesel.

Aransiola et al[16] observed that break thermal efficiency of B10 is very close to break thermal efficiency of pure diesel. Author found 28% brake thermal efficiency by using pure diesel while 31% brake thermal efficiency by using20% neem biodiesel and 80% diesel. Break thermal efficiency of B20 is 14.2 % higher then break thermal efficiency of pure diesel due to the more oxygen content. Author attributed that an increase in break thermal efficiency may be attributed to the complete combustion of fuel because of oxygen present in blends perhaps also help in combustion of fuel.

Shivalaxmi et. al[17] observed that BSFC for the bio diesel and its blend increase due to lower calorific value of biodiesel in comparison with mineral diesel. Author found 0.38 kg/kwhr BSFC with mineral diesel, 0.36 kg/kwhr BSFC with blend 5% neem biodiesel and 95% diesel, 0.4 kg/kwhr BSFC with blend 100% neem biodiesel, which is 5.5% lower Author attributed that as the percentage of bio diesel increases break fuel consumption also increases.

Ramakrishnan et al[18] observed that the specific fuel consumption of blends 20% neem biodiesel and 80% diesel had 8.33% lower than specific consumption of mineral diesel. Author found 0.6 kg/kwhr BSFC with mineral diesel,0.55 kg/kwhr BSFC with blend 20% neem biodiesel and 80% diesel, Author attributed that this happened due to extra amount of oxygen present on the blend which is taking part in combustion process.

Ashraful et al[19] investigated that specific fuel consumption of different load with all percentage of blending was found slightly decrease because of extra oxygen present on the blend which is taking part in combustion process. They observed that the specific fuel consumption of blends 20% neem biodiesel and 80% diesel had 13.33 % lower than specific consumption of mineral diesel. Author found 0.75 kg/kwhr BSFC with mineral diesel, 0.65 kg/kwhr BSFC with blend 20% neem biodiesel and 80% diesel Due to this extra amount of fuel is burning inside cylinder which improves the efficiency which result decrease specific fuel consumption.

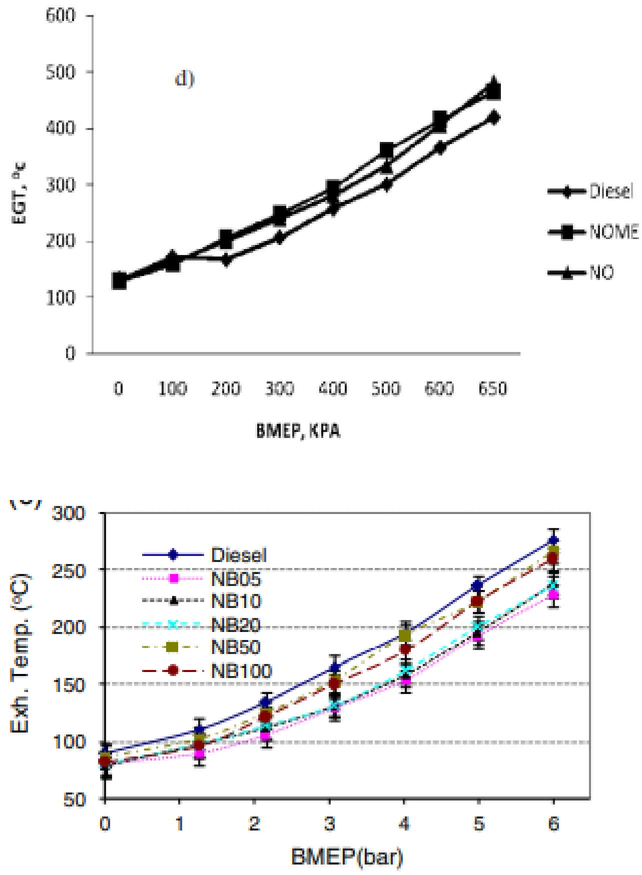

Figure 4Exhaust temperature s BMEP

As shown in figure 4, first figure indicates that only Neem oil shows low exhaust gas temperature as compare to other NOME and pure diesel fuel and second figure indicates that neem oil with 5% blend shows lower exhaust temperature. Here in both cases contradiction shown but from the NOx emission data it can be concluded that exhaust temperature is less as neem oil blending increases as exhaust gas high temperature is also an indication of high maximum temperature throughout the cycle and high NOX emission.

Kaisan et. al.[20] evaluated that exhaust gas temperature for all biodiesel blends is lower than mineral diesel. . Author found 280 ºC EGT with pure diesel, 225 ºC with blend 5% neem biodiesel and 95% diesel, 260 ºC with blend 100% neem biodiesel. Author found that 20 % exhaust temperature decrease with 5% neem biodiesel and 95% diesel blend compare to mineral diesel. They attributed that combustion of higher biodiesel blends start relatively earlier and their combustion ends earlier also compare to lower biodiesel blends.

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Sivasarvanan et al[21] evaulted that exhatst gas temperature for all blends of diesel and biodiesel are lower than the mineral.diesel Author found 287 ºC EGT with pure diesel, 270 ºC with blend 50% neem biodiesel and 50% diesel. Author found that 6 % exhaust temperature decrease with 50% neem biodiesel and 50% diesel blend compare to mineral diesel.Author attributed that this happen due to more oxygen present in the biodiesel and due to that complete combustion is done.

Effect on engine Emission

To identify engine performances when Neem oil biodiesel is used, then different blends have been used. The main concern in engine performance is the Brake thermal efficiency (BTE) and Brake specific oil engine consumption (BSEC). Neem oil biodiesel properties are compared with diesel properties.

The different conventional blends used are represented as B10, B20, and B30. B10 has a ratio of 10% Neem biodiesel to 90% diesel, B20 contains 20% Neem biodiesel to 80% diesel whereas B30 has a ratio of 30% biodiesel and 70% diesel [14]. It has been identified that the Brake thermal efficiency of B10 is higher compared to that of diesel whereas B20 and B30 have lower efficiency compared to diesel. This is because B30 has higher kinematic viscosity which results in a larger diameter of the droplet. This leads to lower brake efficiency.

The brake specific consumption of energy (BSEC) of biodiesel is higher than of diesel. Neem biodiesel blends have lower emissions of harmful gases such as carbon monoxide, carbon dioxide, and smoke among others when compared to petroleum diesel. B10 and B30 blends show a higher emission of NOx emissions compared to conventional diesel. It has also been identified that Exhaust Gas Temperature (EGT) for the blends was lower compared to that of petroleum diesel over the entire load range. [15] Identified that B20 and B30 have cylinder pressure that is almost the same as that of diesel at all loads.

Rathinam et. al[22] found 60 gm/kwhr with pure diesel, 40 gm/kwhr with blend 5% neem biodiesel and 95% diesel, 53 gm/kwhr with blend 100% neem biodiesel. Author found that 33.33 % COx decrease with 5% neem biodiesel and 95% diesel blend compare to mineral diesel. Author attributed that at higher engine loads, all the biodiesel blends except 50% blend show significant reduction in CO emissions. Reduction in CO emission is caused by the presence of oxygen molecules in the biodiesel blends, which facilitates the reburning of CO formed in the cylinder.

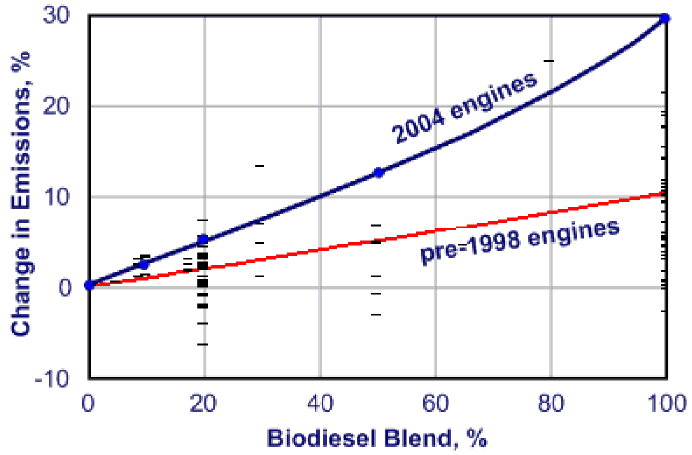

Figure 5 NOx emissions with biodiesel blends: Engine dynamometer tests

does not need any modification since no damage was identified. The blends showed important results for the physical properties such as kinematic viscosity and flash point among others. An increase in alcohol content in these blends led to a decrease in NOx emission, an increase in carbon monoxide emission, and a decrease in emission of hydrocarbons due to their inherent lower energy contents [16].

It has been identified that increases in biodiesel proportions in the blends increases specific fuel consumption and decreasing brake thermal efficiency. For all blends, there is increased emission of Carbon dioxide, carbon monoxide, and hydrocarbons when brake power is increased. An increase in biodiesel proportions in the blends leads to a decrease in Carbon dioxide emission and a decrease in carbon monoxide and hydrocarbons emission. Finally, [7] identified that there was a reduction in emission levels of smoke and carbon monoxide and the emission of NOx increased with an increase in biodiesel from Mahua in the blends. Increased temperatures exhaust gases led to a higher emission level of NOx by all blends of compared to diesel. The figure below shows the performance of CI engine when Mahua oil diesel is used.

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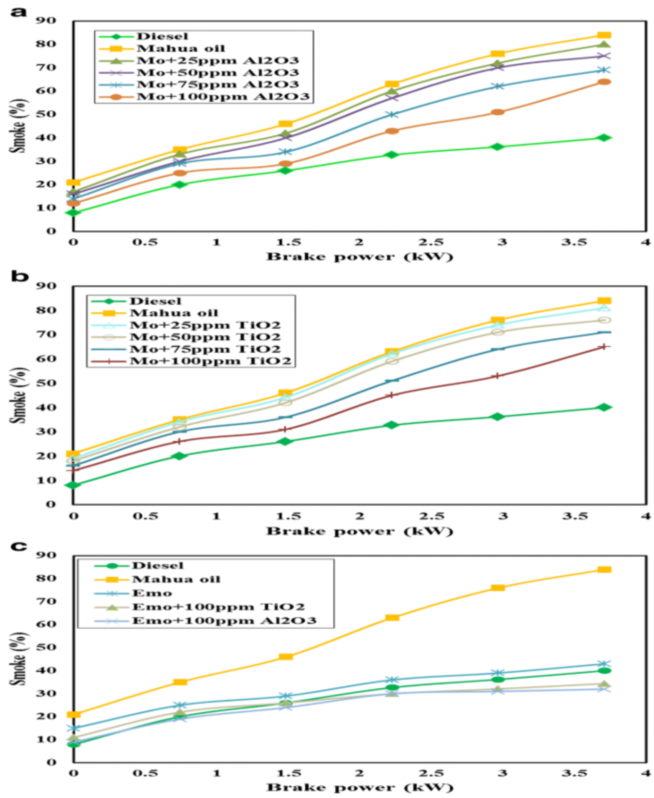


Figure 6: Engine performance on utilization of Mahua oil blends

Karthikeyan et al[23] investigated that emission of Cox for blends 20% neem biodiesel and 80% diesel is 16.67% lower than emission of COx for mineral diesel. They found 60 gm/kwhr with pure diesel, 50 gm/kwhr with blend 20% neem biodiesel and 80% diesel Author concluded that these lower emission of COx may be due to their more complete oxidation as compared to mineral diesel.

In figure 6 comparison of NO emission with respect to BMEP is shown 1st figure indicate that filtered neem oil showing less NO emission as BMEP increases as compare to neem oil methyl easter blend and in second figure its shows that NB50 means nano biodiesel 50% blend shows reduction in NO emission same as neem oil 100%. It means that neem oil from 50% blend to 100% blends able to reduce NO emission.

In figure 8 it shows that neem oil with methyl easter shows less HC emission as compare to neem oil alone or diesel alone. In second figure it shows that NB05 means 5% blend of neem oil shows reduction in HC emission. From the above comparison it is clear that lesser the neem oil lesser will be the HC emission.

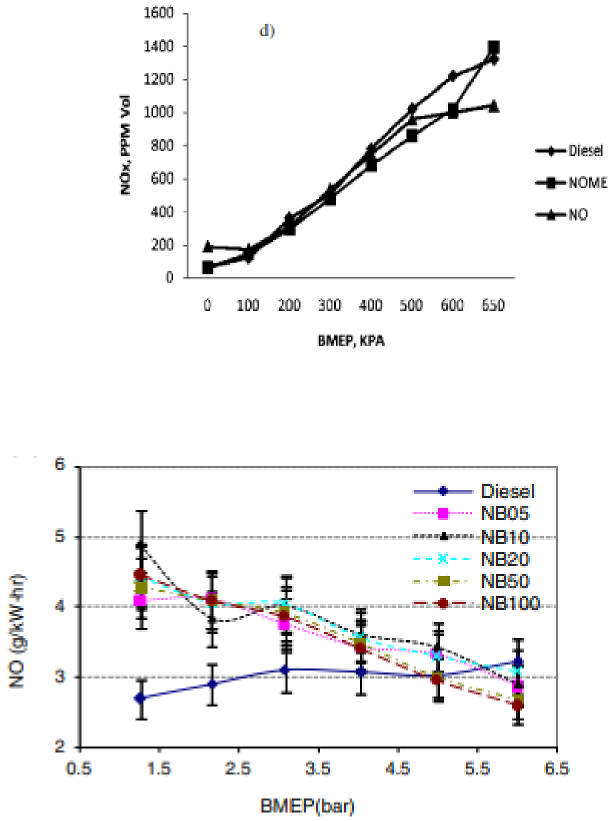


Figure 7 BMEP VS NOx emission

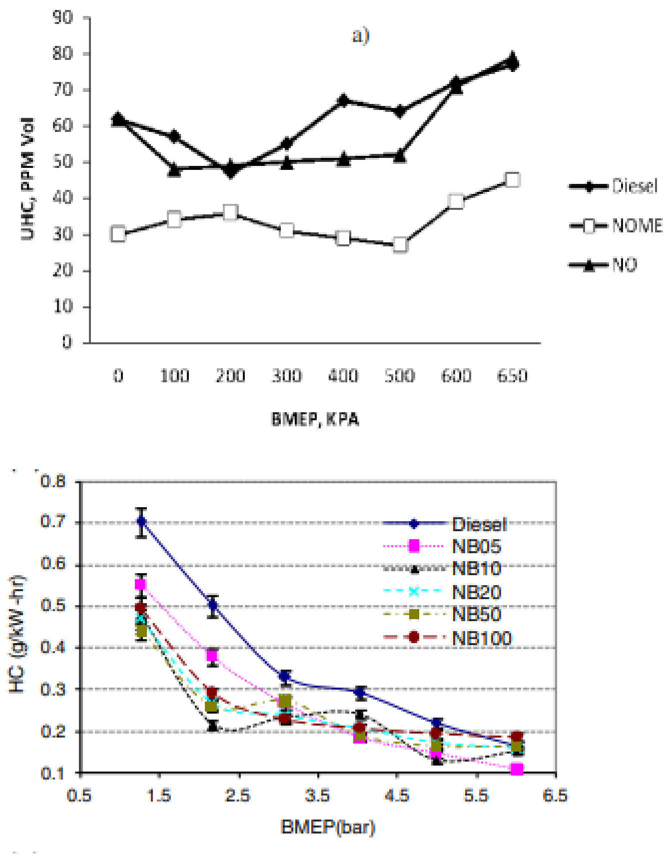
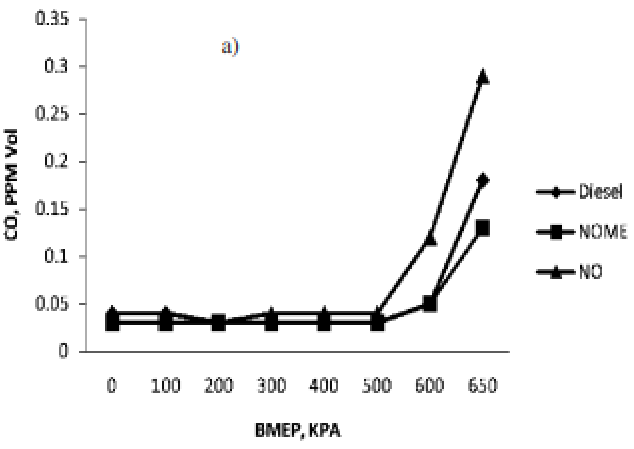


Figure 8 HC emission vs BMEP

Balaji et al[24] observed that emission of Cox for blends 20% neem biodiesel and 80% diesel is 22% lower than emission of COx for mineral diesel. They found 90 gm/kwhr with pure diesel, 70 gm/kwhr with blend 20% neem biodiesel and 80% diesel Biodiesel produce less carbon monoxide than pure diesel because of better combustion due to extra oxygen present in the blend.



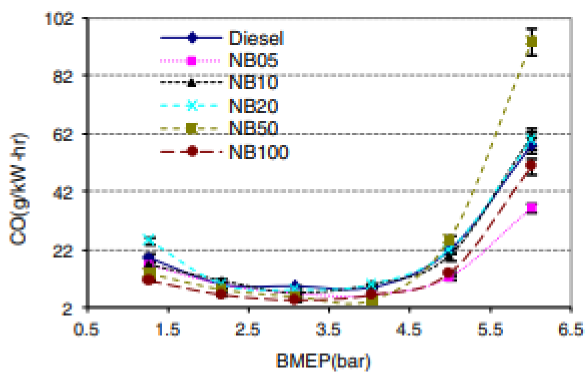


Figure 9 CO emission vs BMEP

In figure 9 it shows that CO emission is less in case of neem oil methyl easter blend at higher BMEP. Neem oil with lower blend proportion 5% will shows low CO emission. It clearly indicates that lower the value of neem oil lesser the incomplete combustion and lesser value of the CO emission.

Nayak et. al[25] investigated that NOx emissions is 2.2% decrease with blends of neem biodiesel and 95% diesel. They found 3.2 gm/kwhr with pure diesel, 2.5 gm/kwhr with blend 100% neem biodiesel. NO formation is dependent on the temperature inside the cylinder and the concentration of available for reacting with nitrogen .higher oxygen content of biodiesel blends increases NOx emissions.

Ali et al[26] investigated that 12% NOX decreses with 30% neem biodiesel and 70% diesel. They found 7.69 gm/kwhr with pure diesel, 6.72 gm/kwhr with blend 30% neem biodiesel and 70% diesel. NOx emission found less compare to mineral diesel due to good mixture formation and lower smoke emissions these factor are highly influenced by viscosity density and volatility of fuel.

Ranjith et al [27] investigated that NOx emissions is 21% lower than for B20 (20% neem biodiesel and 80% diesel biodiesel).Author found that slight decrease in NOx in B20 because of in complete combustion. This may be attributed due to higher viscosity which may lead to poor mixture formation.Author attributed that one of blend of biodiesel increases NOx increases because oxygen present in the blend perhaps also helped in complete combustion of fuel.

Rathinam et. al[28] evaluated that emissions of hydrocarbon is 35.7 % decrease with blends of 20% neem biodiesel and 80 % diesel. They found 70 gm/kwhr with pure diesel, 45 gm/kwhr with blend 20% neem biodiesel and 80% diesel, 50 gm/kwhr with blend 100% neem biodiesel. They found that all biodiesel blends exhibit lower the HC emission compared to mineral diesel this may be due to combustion of biodiesel blends due to presence of oxygen.

Knan et al[29] investigated that emissions of hydrocarbons is 36% lower for blend of 20 % neem biodiesel and 80 % diesel. They found 50 gm/kwhr with pure diesel, 35 gm/kwhr with blend 20% neem biodiesel and 80% diesel. Compare to pure diesel they attributed that the less emission compare to diesel due to good mixture formation.

The major focus was on the brake thermal efficiency and brake specific fuel consumption of the engine powered by the Neem methyl ester and its blends.

Kanthavelkumaran et al.[30] investigated the performance of Diesel Engine on Neem oil in single fuel mode and also on dual fuel mode using the combination of producer gas and oil by varying the injection pressure from 205 bar to 280 bar but at rated speed of 1500 rev/ min and injection timing of 23° before TDC. The brake thermal efficiency of engine over entire load range on single fuel mode using Diesel and Neem oils was around 31 and 26%, respectively, whereas on dual fuel mode with producer gas combined with Diesel and Neem oils was around 24 and 17%, respectively. The brake thermal efficiency of 100% Neem biodiesel was marginally lower than conventional diesel.

Ganeshan et. al.[31] experimentally evaluated the performance characteristics of compression ignition engine (Kirloskar, DM-10) running on neem oil biodiesel blends (B5, B10, B20, B50, and B100) and reported that brake specific fuel consumption and brake thermal efficiency of biodiesel and its blends were higher than mineral diesel. B100 has the highest thermal efficiency among all test fuels. Exhaust gas temperature for all blends of biodiesel was lower than conventional diesel fuel over the entire load range. B5 blend has lowest EGT over entire load range.

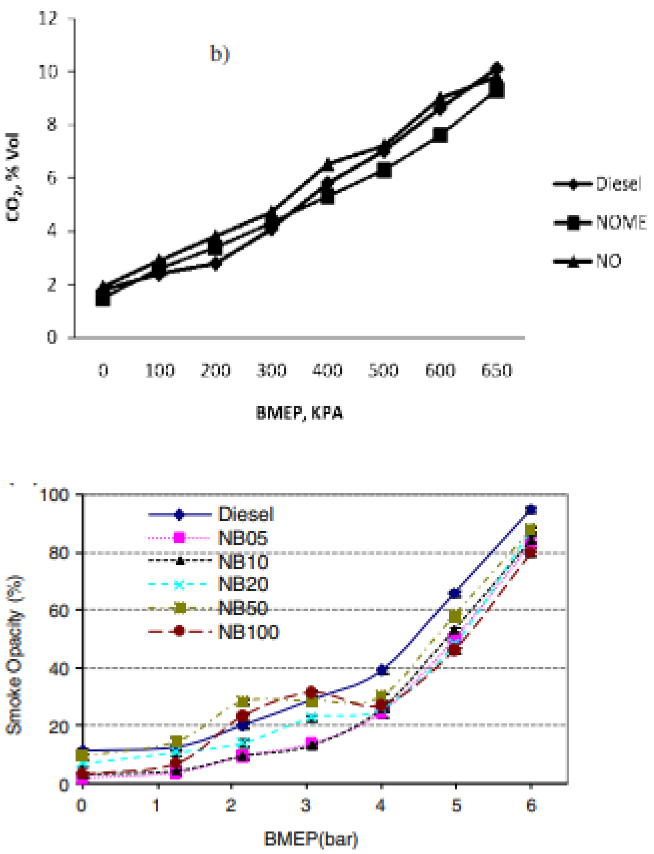


Figure 10 CO2 vs BMEP

From figure 10 it shows that there is no of very less effect of neem oil blend on CO_2 emission and another figure shows that smoke opacity also remains almost same with all amount of neem oil blend proportion. So, one can clearly indicate that neem oil proportion will less effective on CO_2 emission.

Karim et. al.[32] reported the performance characteristics of Neem methyl ester and found that the brake thermal efficiency of blends were closer to mineral diesel but not more than diesel for any blend. BTE of lower blends up to 20% blending was very closer to mineral diesel whereas BSFC was lower at part load and higher at full load in comparison to mineral diesel. Also BSEC of Neem methyl ester and its blends decreased at part load and increased at full load than that of mineral diesel which is due to lower calorific value of Neem methyl ester.

Das et. al.[33] experimentally investigated the effect of antioxidant (Butylated hydroxytoluene) on oxidation stability of Neem methyl ester and performance of direct injection diesel engine fueled with biodiesel derived from Neem. The BTE of engine running on neat biodiesel was lower than mineral diesel at all loads. The biodiesel-antioxidant mixture brake thermal efficiency was slightly lower as compared to neat biodiesel. The biodiesel-antioxidant mixture brake specific energy consumption was slightly higher as compared to neat biodiesel as the percentage of antioxidant added was very small (0.01–0.04%).

Balaji et. al.[34] experimentally studied the effect of antioxidant (A-tocopherol acetate) on the oxidation stability of methyl ester of Neem and performance of diesel engine fueled with Antioxidant containing Neem biodiesel. The BTE of neat biodiesel fueled engine was lower than mineral diesel fueled engine at all loads due to its high viscosity. The BTE of biodiesel-antioxidant mixture fueled engine was slightly lower as compared to neat biodiesel. The brake specific energy consumption of biodiesel antioxidant mixture fueled engine was slightly higher as compared to neat biodiesel as the percentage of antioxidant added was very small (0.01–0.04%).

Shobana et al.[35] reported the performance characteristics on a single cylinder four stroke water cooled DI engine (Xia engine, China, 3.68 kW).The specific fuel consumption of Neem biodiesel was lower than mineral diesel; but at higher load, specific fuel consumption was more for biodiesel on account of its lower calorific value and higher viscosity in comparison to mineral diesel. The BTE of biodiesel was slightly higher as compared to mineral diesel on account of its higher cetane number which was more dominant than its lower calorific value. Exhaust gas temperature was lowered with Neem methyl ester in comparison to diesel. Thus engine performance running on biodiesel was comparable to that of mineral diesel.

Kareemullah et. al.[36] reported the performance characteristics of constant speed (1500 rpm), single cylinder four stroke, direct injection low heat rejection (LHR) diesel engine (TV-SR II, Kirloskar) fueled with methyl esters of cotton seed oil and Neem oil. The brake thermal efficiency of LHR engine fueled with methyl esters of Cotton seed (CSME) and Neem (NME) were lower than that of diesel fueled normal engine by 6.88 and 6.48% respectively. LHR engine fueled with CSME and NME reported higher brake specific fuel consumption in comparison to normal engine fueled with conventional diesel by 28.57 and 10.71%, respectively. Exhaust gas temperature was found to be 9.22 and 10.79% higher for LHR engine fueled with CSME and NME in comparison to normal engine fueled 6 M. CHHABRA ET AL. with conventional diesel fuel. The Maximum EGT with CSME was 491.27°C; with NME was 498.3°C and with conventional diesel was 449.76°C.

Elkelawy et al.[37] reported that engine power reduces slightly due to lower calorific value of biodiesels and with increased biodiesel fuel consumption the power was recovered. Thus, they concluded that small volume of biodiesel blends could replace mineral diesel and also reduce the pressure on scarce resources to great extent without sacrificing the engine performance significantly.

Fadairo et. al.[38] investigated the performance characteristics of various blends of neem oil biodiesel (B 10, B 20, B 30) on single cylinder four stroke water cooled diesel engine and reported that at all test load conditions the brake thermal efficiency of blends were higher than that of diesel fuel, and it was found to be 34% higher for B10 and B20 blends in comparison to diesel fuel. B10 blends gives higher performance as compared to diesel and other higher blends.

Rushi kumar et. al.[39] reported the performance and emission characteristics on unmodified four stroke air cooled single cylinder Diesel engine (Kirloskar, 4.4 kW at 1500 r.p.m) fueled with NB5, NB10 and conventional Diesel fuel. The brake thermal efficiency was higher at full loads for both blends NB5 and NB10 (1.8–3.7%) but it reduces at part load for NB5 (1.7–17.4%) and B10 (7–12.2%) in comparison to fossil diesel fuel.

Bose et al.[40] investigated the performance characteristics of single cylinder air cooled four stroke 4.4 kW Diesel Engine powered by Neem oil biodiesels which was blended with neat diesel at blending ratio of 20/80 by volume at five test load conditions i.e., 0, 25, 50, 75, and 100%. The brake thermal efficiency was claimed highest by neat diesel relative to all test blends. At full load condition (100%) BTE of NME decreased by 10.34%, respectively, relative to neat Diesel. The exhaust gas temperature (EGT) of all test blends was reported higher relative to neat diesel and was reported 5.65% higher at 100% load. Table 4 describes the experimental data related to the performance of engine as reported by the various authors on the basis of test performed on the engine, powered by the conventional diesel fuel and Neem biodiesel and its various blends. Test results shows that the brake thermal efficiency of the engine was varying by changing the test load and by changing the percentage of biodiesel in the diesel-biodiesel blend. The BTE of the engine as reported by majority of researchers was found to be comparable or better for the B20 blend i.e., blend containing 20% of biodiesel in conventional diesel fuel and was reported to decrease with the increase in the percentage of biodiesel in the blend. The pure biodiesel i.e., B100 gives lower brake thermal efficiency in comparison to conventional diesel fuel at all test load condition as reported by the authors in Table 4. The majority of authors claim that BSFC was lower at part load and higher at full load for the engine running on lower biodiesel blends as compared to conventional diesel fuel. The BSFC of higher blends and pure biodiesel powered engine was claimed to be higher in comparison to mineral diesel.

Pravin A. Manade et al.[41] utilized bio fuel from two different production process esterification called ethyl esters and transesterification called methyl ester. They found that fuel is rather viscous compared to diesel. Chemically is equivalent to fatty acid methyl esters or ethyl esters, produced out of triacylglycerol (triglycerides) via transesterification or out of fatty acids via esterification. Transesterification (alcoholysis) is a reversible reaction in which one ester is converted into another by interchange of ester groups. In the reaction one mole of triglyceride oils contained in vegetable oils, animal fats, or recycled greases, reacts with three moles of alcohol to form one mole of glycerol (glycerin) and three moles of the fatty acid alkyl ester (bio-diesel).

R.Senthilkumar et al.[42] observed that the specific fuel consumption of blends 20% Neem bio-diesel and 80% diesel had 8.33 % lower than specific consumption of mineral diesel. Researcher found 0.6 kg/kWh BSFC with mineral diesel, 0.55 kg/kWh BSFC with blend 20% Neem bio-diesel and 80% diesel, Researcher attributed that this happened due to extra amount of oxygen present on the blend which is taking part in combustion process.

Nishant Tyagi et al.[43] observed that break thermal efficiency of B10 is very close to break thermal efficiency of pure diesel. Researcher found 28% brake thermal efficiency by using pure diesel while 31% brake thermal efficiency by using 20% Neem bio-diesel and 80% diesel. Brake thermal efficiency of B20 is 14.2 % higher than break thermal efficiency of pure diesel due to the more oxygen content. Researcher attributed that an increase in break thermal efficiency may be attributed to the complete combustion of fuel because of oxygen present in blends perhaps also help in combustion of fuel.

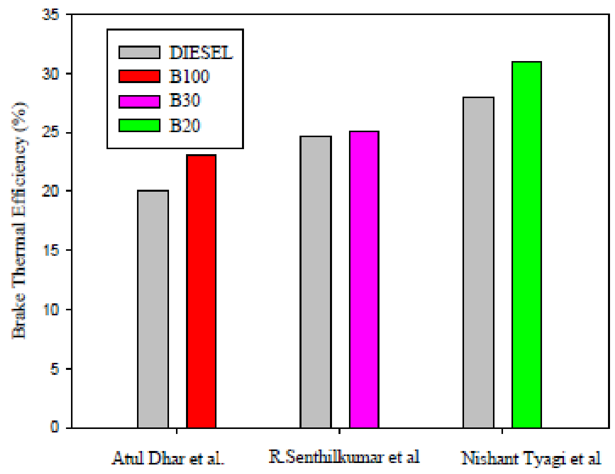


Figure 11Variation in brake thermal efficiency

Atul Dhar et al.[44] evaluated that exhaust gas temperature for all bio-diesel blends is lower than mineral diesel. Researcher found 280 oC EGT with pure diesel, 225oC with blend 5% Neem bio-diesel and 95% diesel, 260 oC with blend 100% Neem bio-diesel. Researcher found that 20 % exhaust temperature decrease with 5% Neem bio-diesel and 95% diesel blend compare to mineral diesel.

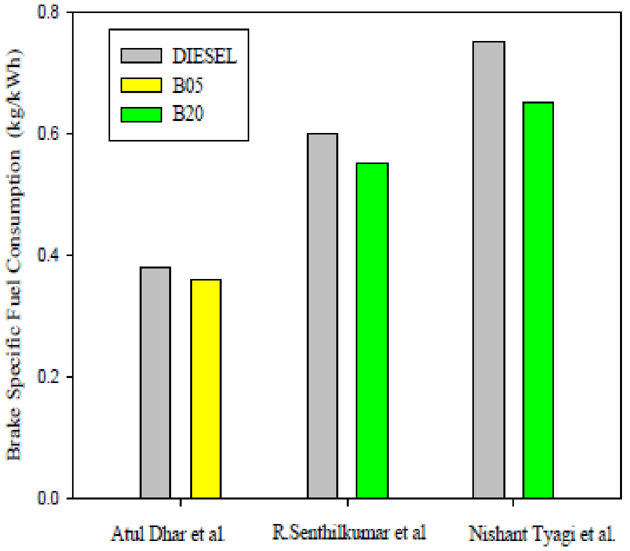


Figure 12Variation n brake specific fuel consumption

They attributed that combustion of higher bio-diesel blends start relatively earlier and their combustion ends earlier also compare to lower bio-diesel blends.

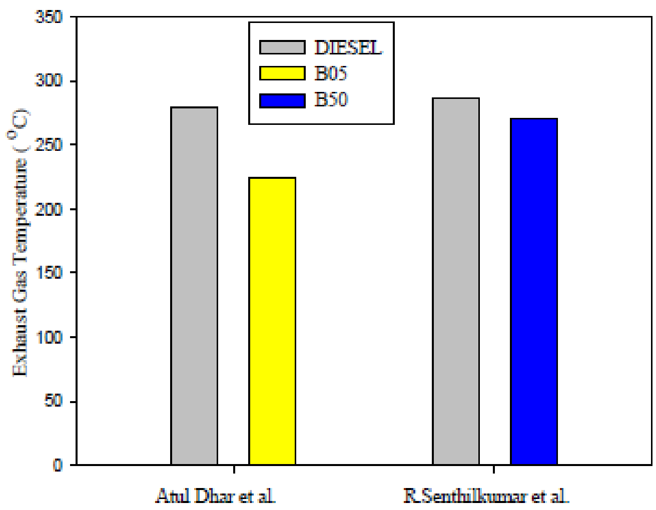


Figure 13Variation in exhaust gas temperature

R.Senthilkumar et al.[45] investigated that emission of CO for blends 20% Neem bio-diesel and 80% diesel is 16.67% lower than emission of CO for mineral diesel. They found 60 gm/ kWh with pure diesel, 50 gm/kWh with blend 20% Neem bio-diesel and 80% diesel Researcher concluded that these lower emissions of CO may be due to their more complete oxidation as compared to mineral diesel.

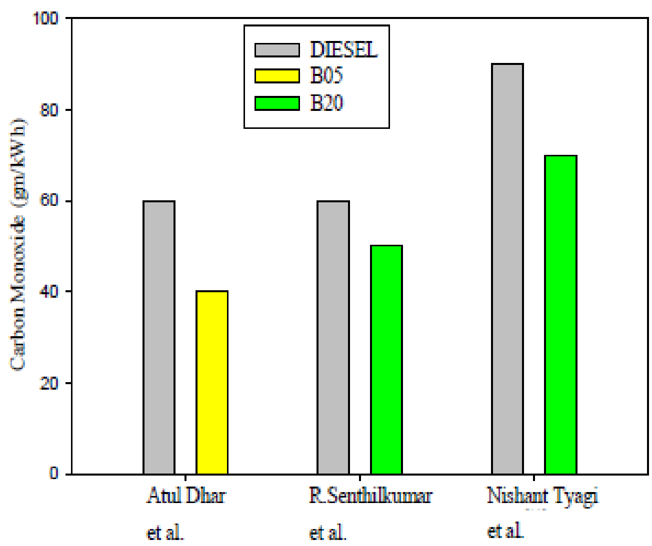


Figure 14Variation in carbon monoxide emission

Nishant Tyagi et al.[46] observed that emission of NOx for blends 20% Neem bio-diesel and 80% diesel is 21% lower than emission of NOX for mineral diesel. They found 9 gm/ kWh with pure diesel, 7.10 gm/kWh with blend 20% Neem bio-diesel and 80% diesel. They attributed that one of blend of bio-diesel increases NOx increases because oxygen present in the blend perhaps also helped in complete combustion of fuel.

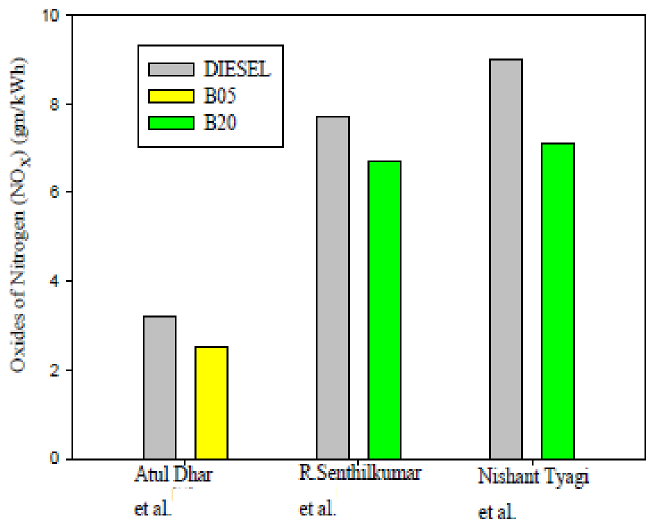


Figure 15Variation in oxides of nitrogen emission

Performance of mixed biodiesel and diesel fuel blends

Lanjekar et al.[47] concluded after a comprehensive review of articles related to the effect of biodiesel composition on biodiesel properties and emission characteristics that NOx emissions, oxidative stability, and cold flow properties impose contradictory requirements on the fatty acid composition of biodiesel. The improvement in one property would lead to deterioration in another property and vice-versa. As per local availability, a blend of various biodiesels can be used to alter biodiesel properties for optimum performance and emission production.

Usta et al.[48] experimented with biodiesel produced from hazelnut soapstock and waste sunflower oil mixture in a Diesel engine. The six fuels were tested in the engine at different engine loads. The test fuels were Diesel fuel No. 2 and blends containing the biodiesel in 5%, 10%, 15%, 17.5%, and 25% proportions by volume. Biodiesel blends produced a slightly higher torque and power at both full load and partial loads. It was found that 17.5% biodiesel addition gave the maximum power and thermal efficiency. At full load, the CO emissions of the blend were higher at low speed and lower at high speeds than those of Diesel fuel, while the blend resulted in higher CO2 emissions. The biodiesel addition slightly decreased the noise. Habibullah et al.[49] evaluated performance characteristics of coconut, palm, and their combined blend with diesel in a single-cylinder diesel engine. The test fuels prepared for performance evaluation were diesel, 30% coconut biodiesel (CB30), 30% palm biodiesel (PB30), and a blend of

15% palm and 15% coconut biodiesel(PB15CB15). PB15CB15 showed slightly higher BTE (1.12%) than PB30 and slightly lower BP and BTE (0.20% and 0.12%, respectively) than CB30 fuel. By contrast, BP decreased by 0.20% compared with that of PB30 and increased by 0.63% compared with that of CB30. PB15CB15 showed a 1.22% higher NOx emission than that of PB30 and 1.20% lower NOx emission than that of CB30. PB15CB15 showed lower CO and HC emissions (2.43% and 9.35%, respectively) than PB30 and slightly higher emissions (2.60% and 7.72%, respectively) than CB30 fuel.

Sanjida et al.[50] experimented with palm-jatropha combined blend on an unmodified diesel engine. Experimental research carried out to evaluate the BSFC, engine power, exhaust, and noise emission characteristics of a combined palm and jatropha blend in a single-cylinder diesel engine at different engine speeds ranging from 1400 to 2200 rpm. Though the PBJB5 and PBJB10 biodiesels showed a slightly higher BSFC than diesel fuel, all the measured emission parameters and noise emission were significantly reduced, except for NO emission. CO emissions for PBJB5 and PBJB10 were 9.53% and 20.49% lower than for diesel fuel. By contrast, HC emissions for PBJB5 and PBJB10 were 3.69% and 7.81% lower than for diesel fuel. The sound levels produced by PBJB5 and PBJB10 were also reduced by 2.5% and 5% compared with diesel fuel due to their lubricity and damping characteristics.

Sridhar et al.[52] carried out performance and emission study of the mix of diesel and blends of biodiesels produced from pongamia pinnata and mustard oils. Six blends namely Blend A-Diesel 90%, 5% each biodiesel by volume basis, Blend B-Diesel 80%, 10% each biodiesel by volume basis, Blend C- Diesel 60%, 20% each biodiesel, Blend DDiesel 40%, 30% each biodiesel, Blend E- Diesel 20%, 40% each biodiesel and Blend FDiesel 0%, 50% each biodiesel by volume were prepared for testing. The thermal efficiency and mechanical efficiency of Blend A were slightly higher than the diesel. Blend B and Blend C were very closer to the diesel values. Blend A and Blend B produced slightly lower CO and CO2 than diesel. The dual biodiesel blends gave higher smoke opacity, HC, and NOx than diesel. But for Blend A, Blend B, and Blend C the smoke opacity was nearer to diesel. Blend A, Blend B, and Blend C can be used as an alternative fuel.

Öztürk[53] assessed the performance, emissions, combustion, and injection characteristics of a diesel engine fuelled with canola oil-hazelnut soapstock biodiesel mixture. The experiments were performed with No.2 diesel (D100) and No.2 diesel/biodiesel blends containing 5% (B5) and 10% (B10) biodiesel fuels. 5% biodiesel addition did not significantly affect the brake specific fuel consumption and the thermal efficiency while 10% addition had negative effects due to the deterioration of the combustion. The advanced ignition delay and the lower heating value with the biodiesel addition generally caused a decrease in the maximum heat release rate and an increase in the combustion duration. B10 causes a slight increase in THC and smoke at all loads. There were no significant changes in CO emission. Although B5 causes a slight increase in NOx emissions, the lower NOx emissions were observed with B10. 5 and 10% biodiesel additions did not significantly affect CO2 emissions.

Khan et al.[54] investigated performance and emission characteristics of a diesel engine using a complementary blending of castor and karanja biodiesel. All biodiesel blends showed higher BSFC than neat diesel. Emissions like CO, HC, CO2, and smoke were improved for the C5K10D85 blend due to the presence of oxygen content in biodiesel due to the higher cetane number of blends. However, NOx was found to increase for all biodiesel blends. Emissions also increased with the increasing blending of castor biodiesel in fuel blends. Among the tested blends, C5CK5CD90, C5K10CD85, C15CK5CD80,. C10CK5CD85, and C5CK15CD80, C5CK10CD85 blend was found to be a more suitable and sustainable fuel blend to replace conventional diesel

Ruhul et al.[55] studied engine performance and emission characteristics of Croton megalocarpus and Ceiba pentandra complementary blends in a single-cylinder diesel engine. The test fuels were Diesel, CMB20, CPB20, CMB15CPB05, CMB10CPB10, and CMB05CPB15. Compared to ordinary diesel, for all tested blends, the average engine brake power was lower about 0.53% to 3.70%. BSFC was higher about 3.90% to 9.74% than that of diesel mainly owing to their lower heating value and higher density and viscosity. The BTE was slightly lower (about 0.50–5.97%). The average NOX emission was 10.50% to 18.66% higher. The CO and HC emissions were reduced to an extent of 1.09–5.21% and 1.48–8.38%.

The Engine Manufacturers Association (EMA) and a consortium of fuel injection equipment manufacturers recommend the use of biodiesel blends that contain no more than five percent by volume biodiesel (B5). Higher concentrations such as B20 are not universally accepted, however, some OEM's have produced models that can run on B20. The neat biodiesel usage as fuel requires some engine modifications. The general concern with higher-than-B5 is the lack of convincing data to ensure that use of such fuels does not lead to engine performance issues, such as filter plugging, injector coking, piston ring sticking and breaking, elastomer seal swelling and hardening/cracking, and engine lubricant degradation[56]. In most of the reported studies 20% blend of Jatropha biodiesel with petro-diesel is found to be suitable for normal operations without any modifications in engine specifications. Thus as a technological dimension it would be more appropriate to go for blends rather targeting usage of 100% biodiesel in existing engines or developing engines for operating on biodiesel only[57].

Conclusion

Biodiesel has attracted great attention today as an alternative fuel. This is because it has many benefits accrued to it. These benefits include its non-toxicity, environmentally friendly, renewability, and biodegradability. It can be produced from oils that are non-edible such as Neem oil which is readily available. The transesterification process is commonly used in the production of biodiesel since it involves the reduction of the viscosity of the oil in presence of alcohol. The factors affecting the production of biodiesel include reaction's temperature, reaction's time, the type and amount of catalyst used as well as mixing intensity among others. Therefore, this paper addresses the methods used in biodiesel production, gives a brief discussion of factors affecting production as well as biodiesel effects on engine performance and emission of exhaust gases.

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