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The Performance and Emission Analysis of a Diesel Engine Using Vegetable Oil Blends and Bio-Diesel as Fuel - A Review

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Abstract

Conventional fuels are depleting rapidly, releasing greenhouse gases, and increasing prices. Vegetable oils, being renewable, biodegradable, and green, can be used as an alternative fuel. Research has been conducted on bio-diesel and straight vegetable oil as fuel for internal combustion engines. This review study compares the physio-chemical parameters, chemical composition, performance, and emission characteristics of a diesel engine running on different straight vegetable oils. The study found that bio-diesel mixes produced higher brake thermal efficiency, mechanical efficiency, and lower emissions compared to pure diesel. The project also investigated the viability of using clean Beef Tallow Oil (BTO) in a compression ignition engine directly. Various vegetable oils were used for experimental investigation, with no modifications required. In this study preheating of Thumba vegetable oil is carried out to enhance the Reynold's number by reducing the viscosity of the oil. Instead of trans-esterification process preheating was carried out by utilization of heat of exhaust gases and temperature of exhaust gases coming out from the exhaust manifold was also lowered. In this study no engine modifications were required. By reviewing all mentioned papers it was found that the research work which has been carried out was not done in researches which were previously carried out. Whatever researches we have mentioned in this review paper were not mentioned in previously published review papers. Most of the papers bio-diesel were prepared and utilized along with diesel for for performance and emission analysis. In this review paper a new thing which we mentioned is utilization of heat of exhaust gases for preheating of vegetable oil by fitment of heat exchanger in between outlet of exhaust manifold and fuel supply system. So this is the novelty work which has been carried out.

Keywords: *Bio-diesel, Brake Thermal Efficiency, Diesel Engine, Emission Characteristics, Performance Characteristics, Specific Fuel Consumption, Trans-Esterification*

1.0 Introduction

The world is experiencing problems with energy demand, the depletion of fossil fuel resources, and rising petroleum costs. Bio-diesel is made from vegetable oils and has been suggested as an alternative fuel. It has already been performed research on combining diesel and a single bio-diesel. There have been few experiments combining two distinct bio-diesel blends with diesel, so there's still much to learn. In order to plot the engine's performance and emission characteristics, a single-cylinder, water-cooled diesel engine with the prepared test fuels is run

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under various load conditions. The experiment's findings indicate that using improves oxidative stability, kinematic viscosity, low-temperature properties, and brake power and thermal efficiency. Pollutants such as linoleate are significantly impacted by fuel quality. Due to the overuse of petroleum-based fuels in industry and automobiles, the world is today facing serious challenges like environmental degradation, a global energy crisis, and global warming. As a result, there is a growing awareness throughout the world about the need to look into alternative fuel sources for engines in order to avoid a gasoline shortage. To develop a suitable alternative fuel to diesel fuel, such bio-diesel, much research is being conducted. Among the non-edible sources include rapeseed, canola, beef tallow, Mahua, Karanja, neem, Jatropha, and simarubba oils.

Trans-esterified derivatives of vegetable oils appear to be the most feasible means of utilizing bio-origin vegetable oils as replacement fuels in compression ignition engines. In the current study, various non-edible rapeseed oils were converted into bio-diesel using tans-esterification, and the fuel's characteristics were compared to those of regular base diesel fuel[1].

Previous research studies have examined the Engine efficiency that run on diesel fuel, canola bio-diesel, and 10% oil (10% by volume (BD-10), 2 or 0 % by volume (BD-20), 30% by volume (BD-30), 40% by volume (BD-40), 50% by volume (BD-50), and 100% by volume (BD-100))[2].

These experiments were conducted on a four-stroke, single-cylinder, water-cooled, vertical, high-speed diesel engine with different loads at a constant speed of 1500 rpm. The results were displayed as BSFC, mechanical efficiency, BTE, and emission parameters for CO, CO_2, HC, and NO_X. The research findings indicate that blends of biodiesel, including BD-10, BD-20, and BD-100, offer superior BTE mechanical efficiency in comparison to pure diesel. CO, CO_2, HC, and emissions were lower for BD-10, BD-20, and NO_X for BD-100 Bio-diesel blend, with the exception of a 20% load. Furthermore, it was discovered that compared to pure base diesel, pure bio-diesel (BD-100) had lower emissions of CO_2, HC, and NO_X[2].

The second review looks at how an antioxidant-equipped diesel engine performs and what kinds of emissions it produces. Tallow bio-diesel was produced from tallow vegetable oil by the process of trans-esterification employing sodium hydroxide as a catalyst. Physical defects in bio-diesel, or beef tallow oil, such as its high density and viscosity, prevent atomization and raise smoke, CO_2, and HC emissions. The study aimed to enhance the engine's performance and reduction in percentage in flue gases and explore the feasibility of use clean Beef Tallow Oil (BTO) in compression ignition engines directly[3].

The effects of mixtures on nitrogen oxides, hydrocarbons, carbon monoxide, and carbon dioxide were investigated using emission testing. Blend A was shown to have a higher Brake Thermal Efficiency than diesel. Nitrogen oxide, hydrocarbon, and smoke emissions from dual bio-diesel blends were greater than those from diesel. Dual biodiesel mixes did, however, produce exhaust gases with a lower temperature than diesel.

Elsanusi OA *et al.,* were examined the properties of emulsion fuel at various water concentration levels and how they affect a light duty diesel engine's performance and emission characteristics. Three different engine speeds were used in this experimentation as 1200, 2100 and 3000 rpm with 3 loads as 20%, 50% and 80%. Emulsification of diesel and bio-diesel blends up to 40 by step of 10 was carried out using 3 different concentrations of water, 5%, 10% and 15%[4].

Atmanli A *et al.,* have evaluated the effect of using *n*-butanol in vegetable oil–diesel fuel blends on engine performance and exhaust emissions of a direct injection diesel engine operating at full load (100% throttle conditions) with different engine speeds without any engine modification[5].

Mofijur M *et al.,* have studied the production of waste cooking biodiesel as an alternative fuel for diesel engine. The bio-diesel was produced through conventional trans-esterification process using the base catalyst as Potassium Hydroxide. A multicylinder diesel engine was used to evaluate the emission of B20, 20% waste cooking bio-diesel fuel at different speeds and full load conditions. It was found that the characteristics of bio-diesel are within the limit of specified standards[6].

Srithar K *et al.,* have carried out experimental investigation of diesel engine by using combinations of two bio-diesels made from mustard oil and pongamia pinnata oil which are combined with diesel at different ratio of mixing. It was observed that engine performance was improved but emission characteristics were poor[7].

Bhabani Prasanna Pattanaika and Swarup Kumar Nayaka[8] conducted experimentation in order to compare the performance and emission characteristics of a diesel engine with straight vegetable oil in addition to those of a diesel engine. The produced bio-diesel underwent a number of tests to determine its thermodynamic characteristics, including ash content, heating value, and another thermodynamic properties. By heating 10 milliliters of fuel in a cubicle for two hours at between 50 and 60 degrees Celsius, the amount of ash content was ascertained. After the cubicle is heated, the only material left inside is ash, which is weighed to find out how much ash is there. The thermodynamic properties of bio-diesel were measured using suitable apparatus, and the results were compared to base diesel. Following the experiment, other percentages of additives were mixed with plain vegetable oil to create different blends, such as BD95, BD90, BD85, and so on. BD95 stands for 95 percent bio-diesel and 5 percent additive. There are numerous uses for the engine that was employed in the experiment.

Narayan Lal Jain, S. L. Soni, *et al.,* employed Thumba oil, for experimental analysis[9]. Thumba oil can be blended with diesel fuel and heated utilizing the waste heat of engine exhaust fumes to lower viscosity, as an alternative to transesterification, which requires chemicals and process heat that are unavailable in remote areas due to logistical concerns[10]. The durability research of a compression ignition engine using diesel and vegetable oil mixes called Thumba was conducted by Narayan Lal Jain *et al.,* They conducted a long-term durability test and ran the engine for 512 hours[11]. To find out how the improved Thumba oil blend with diesel affects the internal engine parts over time, they conducted an experimental investigation. For long-term durability, Narayan Lal Jain *et al.,* studied compression ignition engine running on a warmed, optimized Thumba blend (B20) of diesel. This study looked into diesel engine parts, lubricating oil characteristics, and exhaust pollutants. According to the study's findings, a diesel engine running on a warmed, optimized Thumba blend (B20) may run on this fuel for an extended period of time with just minor adjustments to the engine's maintenance plan. The effect of compression ratio on diesel engine has been investigated by Anmesh K. Srivastava *et al.,* connected to a dynamometer using eddy current[12]. First-ever neat diesel operations were conducted by Anmesh K. Srivastava *et al.,* at CR of 18, ignition pressure of 21 MPa. The engine was warmed up by running it without any load for a while. The engine was tested during the experimentation process at no load, medium load, and full load conditions for different compression ratios with 3500 W serving as the full load[12]. The experiment's findings led to the following deductions: The increased energy content of acetylene in comparison to diesel fuel is the primary reason for the significant improvement in engine performance in dual-fuel mode. In comparison to pure base fuel mode, Brake Thermal Efficiency enhanced by 2% in dual-fuel mode at both CR 20 and CR 21. As a result, Brake Specific Fuel Consumption reduced in dual-fuel mode. Carbon monoxide emission was found to be lower in dual-fuel mode at higher loads and higher in low loads compared to base fuel mode. In the case of the dual-fuel option, Carbon monoxide emission decreased as compression ratio increased. Research revealed that CO emissions in the dual-fuel mode at CR 21 and CR 20 were lower than those in the diesel mode at CR 20 when the load reached 60%.

In order to determine engine efficiencies with its emission plots at the ideal compression ratio (CR 21), experiments were conducted[12]. Using ethanol and enzymatic catalysis, Mata T.M. *et al.,* produced biodiesel from corn oil[13]. Mata T.M. *et al.,* conducted experiments and used enzymatic catalysis with ethanol to produce biodiesel maize oil. Additionally, the biodiesel's quality was evaluated based on the key elements outlined in the EN14214:2009 standard. Results have indicated that for the reaction circumstances specified above, it is possible to generate a better grade biodiesel for the numerous characteristics tested, even though some of the determined parameters are outside of these standard limitations[13].

Tony Roskilly *et al.,* have studied the effect of nanoparticles with aluminum coating as additive to bio-diesel-diesel blends on efficiencies with its emission plots of diesel engine[14]. The study conducted by Hoang aims to improve the heat efficiency of diesel engines by using exhaust gas energy to heat pure vegetable oil as fuel[15]. Currently, most exhaust gas energy is used in ocean ships and heat exchangers. In Vietnam, small diesel engines with less than 100 HP can use pure vegetable oil as fuel. The research will focus on designing, fabricating, and installing heat exchangers to convert diesel engines to

use pure vegetable oil. B. Ashok Kumar *et al.,* have done the experiment by mixing two bio-diesels in diesel to get efficiency plots of single cylinder diesel engine[16].

Aparna Singh *et al.,* have done the experimental investigation on diesel engine to get emission and performance characteristics of the diesel engine using bio-diesel produced by trans-esterification process from Jatropha oil[17]. Hüseyin Aydin and colleagues conducted an experimental investigation on a diesel engine powered by kerosene, which was utilized to power a generator that used sunflower biodiesel. They have performed investigation to get its all characteristics[18] have seen influence of alumina nanoparticles, ethanol and isopropanol blend as additive with diesel soybean bio-diesel blend fuel. T. Shaaf *et al.,* have completed experimental study to plot performance, and flue gas % graph of compression ignition engine[19].

Debbarma et al., conducted a study where they blended neem and karanja bio-diesel to create a mixture called KNB20. This mixture was made up of 20% neem bio-diesel and 80% karanja bio-diesel. They examined the physical and chemical properties of this blend and performed experiments on a diesel engine to evaluate its performance. Brake Thermal Efficiency (BTE), Brake Specific Fuel Consumption (BSFC), and exhaust emissions were measured and tested under various load conditions[20]. *Balaji et al.,* focused on investigating the impact of using neem oil as a fuel in a diesel engine. They investigated the emissions of a diesel engine running on neem oil, including various pollutants which are nothing but flue gases[21].

The study revealed that the presence of diesel antioxidants in neem oil led to increased fuel consumption. The study's results showed that the B10 blend performed better and had lower pollutant emissions compared to pure diesel. Specifically, B10 displayed higher Brake Thermal Efficiency (BTE) than pure diesel. Additionally, when compared to pure diesel, B10 demonstrated considerable reductions in Carbon monoxide (CO), Hydrocarbon (HC), and Nitrogen oxides (NO_X) emissions, with declines of 23%, 8.5%, and 22%, respectively. *Md. Hasan Ali et al.,* investigated the production and quality of bio-diesel derived from neem oil. Neem seed oil was found to contain approximately 30-40 % oil. The study focused on the transesterification process to convert neem oil into bio-diesel. The ideal parameters for the manufacture of biodiesel were ascertained by experimenting with various temperatures and molar ratios of neem oil and methanol. According to the study's findings, the greatest yield of biodiesel, as well as the creation of glycerin and soap layers, were obtained at temperatures between 55 and 61°C when methanol and neem oil were mixed in a 3:1 molar ratio. In conclusion, bio-diesels derived from neem and cotton seed oil show promise as alternative fuels for diesel engines. While they may have a lower energy density and calorific value than pure diesel, they offer the advantages of higher Brake Thermal Efficiency and reduced emissions. Further research is needed to optimize the blend ratios and enhance the performance of these bio-diesels in C.I. engines[22,23]. Studies indicate that alcohol and biodiesel are important substitute fuels for contemporary diesel engines. Minimal engine adjustments are required for blending biodiesel-diesel, biodiesel-alcohol, alcohol-diesel, and biodiesel-alcohol-diesel. Non-edible oilseeds like karanja, mahua, and jatropha can be used to make biodiesel, which can help meet the world's demands for food and fuel security. Because biodiesel and alcohols contain more oxygen than diesel, they burn completely. They also use more gasoline and have a lower calorific value and energy density, which reduces brake power. Alcohol and biodiesel also lower emissions of smoke, soot, CO, and UHC. On the other hand, the concentration of NOx can be reduced by adding bioethanol[24]. Nithyananda *et al.* compares neem biodiesel blends with diesel in a single cylinder, four stroke diesel engine and assesses the generation of neem oil methyl ester using sodium hydrogen catalyst. The study comes to the conclusion that neem biodiesel can be utilised as an alternative fuel in a 20% blend with petroleum diesel[25]. Kumar and Kumar demonstrates that biodiesel may be produced from cottonseed and neem oil, minimising negative environmental effects and reliance on imported crude oil. According to the study, CSOME-C20 blends had characteristics more akin to diesel fuel, decreased smoke and pollutants, and improved brake thermal efficiency. CSOME-C20 is the ideal blend for diesel engines[26]. *Anbumani et al.,* reported that blending vegetable oils with diesel had positive effects on the physical and chemical properties of the oils[27]. It has been found that the cetane number of the blends behaves like that of diesel. By conducting tests on a constant speed C.I. engine with different loads, they determined that a 20% oil blend demonstrated improved engine

performance in comparison to pure diesel. Additionally, their observations revealed that a 20% mustard oil blend with diesel blends. Abdulkadir *et al.,* evaluated the combustion and exhaust characteristics of a diesel engine by an experimental investigation conducted at varying loads. Their findings indicated that diesel had better fuel economy when compared to blends. However, they discovered that B20 blends consistently exhibited higher torque, brake power, and thermal efficiency compared to diesel. Among all the samples examined, diesel had the lowest NO_X emission rate[28].

Yogesh Tamboli and colleagues conducted an experiment on bio-diesel made from neem oil using a process known as transesterification[29]. They concentrated on determining the best bio-diesel yield at different temperatures and neem oil/methanol molar ratios. The study also evaluated the viscosity and acidity of the biodiesel. Anand Prakash Mal and his associates looked into how different diesel and biodiesel mixes affected a Kirlosker engine's performance in terms of a number of criteria. They examined various blends such as B20, B20, and B30 and assessed their performance and emissions under varying loads[30]. Sivanathan Sivalakshmi and his team conducted a study to determine the performance of a compression ignition engine at full load condition. Their conclusions indicated that Neem Oil Methyl Ester (NOME) had a higher peak pressure, although neat neem oil and NOME had a lower peak heat release rate[31]. Furthermore, NOME burned for longer than pure diesel at all load circumstances and had a higher Brake Thermal Efficiency (BTE) than neem oil.

Shrivastava and associates worked on esterifying neem oil in order to produce bio-diesel. Using a compression engine, they conducted tests in which they blended diesel with different amounts of bio-diesel and Diethyl Ester (DEE). Smoke, CO, and NO_X emissions were reduced as a result of this combination[32]. The findings suggested that bio-diesels and DEE held promise as viable fuels due to their superior performance and emissions characteristics. Diesel-based mixtures of pongamia and neem oils were used in a performance study conducted by Naresh Kumar Konada and colleagues. They used the transesterification technique to create different bio-diesel blends (B10, B15, B20, B25, and B30). Different engine performance parameters were measured for each blend, with a specific focus on Pongamia oil and Neem oil as bio-diesel[33]. Based on the outcomes, the researchers recommended a suitable bio-diesel blend that would optimize engine performance. Balaji and their team conducted experiments to test the efficiency of methyl ester with Neem oil on diesel engines at varying injection pressures[34]. As the injection pressure of bio-diesel increased, there was enhancement in engine efficiency and less fuel was consumed by the engine. The optimal results, according to the researchers, were obtained with an injection pressure of 240 bar. This study encompassed measurements of both engine performance and emissions, with the optimal injection pressure resulting in reductions in CO, CO_2, unburned Hydrocarbon (HC), and NO_X emissions. Sivanathan and their colleagues conducted an investigation on a diesel engine and discovered that combining an antioxidant additive with Selective Catalytic Reduction (SCR) led to an 82% reduction in NO_X emissions. Unburned hydrocarbon and CO emissions increased, although BTE and BSFC were not significantly impacted. Devaraj and his team conducted a study to compare how effective Dimethyl Carbonate (DMC) is as a fuel additive in reducing emissions from diesel engines. A single-cylinder, four-stroke diesel engine was used to test three different fuels: normal diesel fuel, B100 biodiesel with DMC, and biodiesel derived from neem oil (B100). Their results demonstrated that adding DMC to biodiesel significantly decreased the levels of CO and HC exhaust emissions as compared to utilizing simply base fuel. Suresh *et al.,* conducted a separate investigation to see how incorporating Graphene Nano Platelets (GNPs) into neem oil as a lubricant would impact its performance. They found that using a concentration of 1 wt. % of GNPs in neem oil resulted in the lowest friction coefficient and the smoothest wear scar diameter. This highlights the advantages of using GNPs in neem oil as a lubricating agent. Mohammed Hassan Jabal and his colleagues researched the potential of using a sunflower-based lubricant in combination with diesel fuel. They discovered that applying the lubricant based on sunflower had a considerable impact on lowering emissions of carbon monoxide (CO), carbon dioxide (CO_2), and hydrocarbons (HC). They did this by following ASTM rules (ASTM 4172-B). The effects of adding ethanol to neem oil methyl ester in a compression ignition engine running at varying loads and a steady speed were investigated by Sivalakshmi and colleagues. At greater engine loads, they discovered

that ethanol mixes reduced % of flue gases but increased HC emissions. Ethanol initially raised NO_X emissions but eventually reduced them.

Thirumalai and colleagues found that a mixture of 10% neem oil butyl ester in diesel generated superior results and lowered emissions of CO, CO_2, and HC when they investigated bio-diesel with neem oil. The study[35] also included information on the various thermodynamic properties of neem oil and butyl ester. T. M. Yunus Khan *et al.,* found that blends of Neem bio-diesel and diesel outperformed blends of Karanja bio-diesel and diesel in terms of viscosity, heating value, and thermodynamic properties. However, when higher concentrations of Neem (NOME20GO105) and Karanja (KOME20GO105) blends were combined with B20-nano, the BTE decreased to 32.5%, which is lower than that of diesel[36]. Furthermore, Neem and Karanja blends were able to decrease fuel requirement by 10% and 11% respectively, in comparison to B20 blends. In a different investigation, Sharma *et al.,* looked at a diesel engine with a single cylinder and discovered that neem oil significantly reduced the different emissions by 2-5 %. Moreover, there was enhancement in mechanical efficiency and with reduction in fuel requirement. The researcher have achieved economy in their investigation[37]. Mathalai Sundaram and his team conducted a study to investigate the % of flue gases of combining Di-Methyl Carbonate (DMC) with neem oil diesel mixture. In comparison to diesel fuel, their results showed that adding 5% and 10% DMC by volume to BD100 reduced Hydrocarbon (HC) emissions by 7.3%, 8.1%, and 12.5%, respectively. However, all three blends showed higher Nitrogen oxide (NO_X) emissions compared to diesel fuel[38]. Sivasubramanian Rathinam and his colleagues investigated the usage of diesel fuel, neem oil biodiesel, and alcohol blends at 10% and 20% ratios. All engine loading conditions saw a decrease in smoke, NO_X, HC, and CO emissions when alcohol was added to bio-diesel. When L-ascorbic acid was added to orange peel oil bio-diesel, Nataraj Ganesan and colleagues assessed the efficiencies and exhaust gases coming from exhaust manifold of CI engines. Various fuel samples were made with the antioxidant ingredient in different proportions. In comparison to the gasoline mix containing 20% Orange Oil Methyl Ester (OB20), the antioxidant's addition resulted in a decrease in Brake Thermal Efficiency (BTE)[39]. The use of neem oil blends in a particular type of diesel engine was studied by G Balaji and his colleagues. They found that using a neem oil blend reduced CO_2 emissions by 18.4%, especially when paired with Carbon Capture and Storage (CCS) systems.

The portion of the research goal to assess the effect of new generation fuel on diesel engine performance has been covered by Mohamed Beriache *et al.,* For their experimental research, they have used diesel and ethanol and methanol mixtures[40]. To improve performance, they have also looked at how the fuel mixture behaves in the Cl engine. The goal of this study is to assess how next generation fuel affects diesel engine performance[40]. This study is a component of that goal. More GV *et al.,* have done experimental study using biodiesel blends produced from cooking oil. They were studied the performance as well as emission characteristics of single cylinder diesel engine. They found better results. They also studied physical and chemical properties of cooking oil. They were observed that the physical properties (density and viscosity), chemical properties (cetane number and heating value) and thermodynamic properties were enhanced by addition of Di-ethyl ester (DEE)[41]. More GV *et al.,* have studied effect of compression ratio on performance of diesel engine using biodiesel produced from waste cooking oil. They observed enhancement in BTE by 16.06% and decrease in fuel consumption by 4.12 %[42]. More GV *et al.,* investigated the combined effect of compression on performance as well as emission characteristics. This study provides ecofriendly working conditions which results in fewer emissions and improved performance. In this investigation it was also observed that at higher compression ratio Nitrogen dioxide was reduced and at lower compression ration carbon monoxide percentage were reduced[43]. Alahmer A *et al.,* have utilized 20% bio-diesel produced from vegetable oil and 80% diesel on single cylinder diesel engine. In this study it was concluded that emission characteristics observed are good using bi-diesel as compared to that of 100% diesel. So carbon monoxide percentage was reduced and carbon dioxide percentage was increased. Using 20% biodiesel with 80% diesel, BTE was observed to be improved[44]. More GV *et al.,* have done the characterization of bio-diesel blends using chromatography infrared spectroscopy element analysis. In this study it was observed the improvement in physiochemical properties as well as thermal behavior. In this investigation combustion characteristics also

observed to be improved[45]. More GV *et al.,* have done study of mixed dairy waste and Karanja oil, bio-diesel production using Taguchi L9 orthogonal array and charaterization of Karanja oil bio-diesel blends to study it's suitability as a renewable alternative fuel through gas chromatography, infrared Spectroscopy element analysis[46].

In this review paper various vegetable oils were utilized for production of bio-diesel for investigation of diesel engine. And trans-esterification process was utilized for bio-diesel production. Vegetable oils used were Sunflower oil, Karanja oil, Thumba oil, Jatropha oil etc. There are very few studies on neem vegetable oil. In one of the study Thumba oil with preheating method is utilized for improvement in calorific value and decrease in viscosity. This is the research gap found by studying various papers mentioned in references section.

2.0 Summary

A bio-diesel production process is shown in Figure 1.

In this study, 4-cylinder base engine is utilized. To apply loads, an eddy current dynamometer was used. Several experiments were conducted with mixtures of rapeseed oil bio-diesel and pure diesel. Table 1 lists the tested fuel's thermodynamic characteristics. Figure 2 shows the experimental set up with engine parameters[1].

According to the second study, Canola oil blended diesel has become a viable substitute for Internal Combustion Engines (ICEs) due to its ability to meet certain requirements. These include the need for minimal modifications, the provision of engine life without compromise, and the absence of any environmental or public health risks during production, transportation, storage, or use. It has been demonstrated that using crude

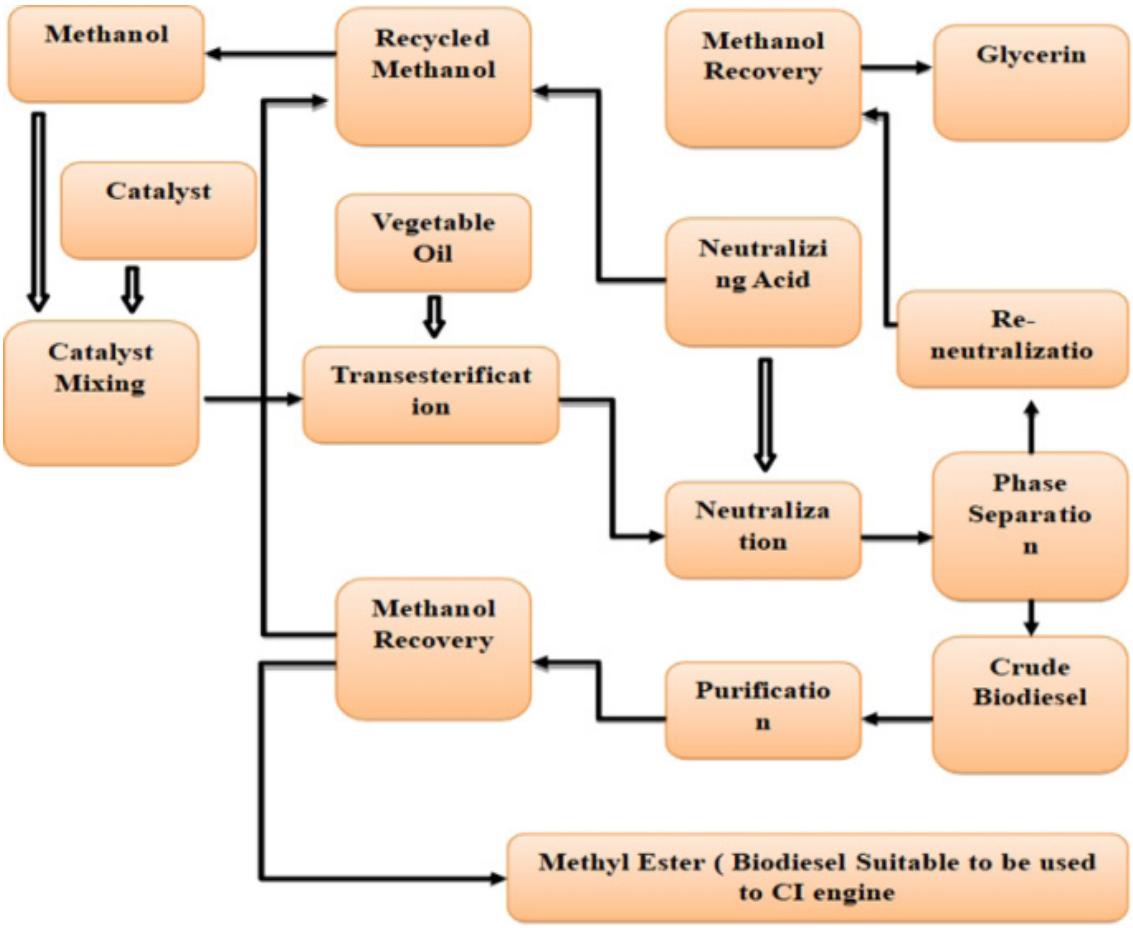


Figure 1. Bio-diesel Production Process[1].

Table 1. Heating value of various fuels[1]

Sr. No.	Fuel	Heating Value (MJ/Kg)
1	Base Fuel (Diesel)	48.0
2	Blend-A	47.2
3	Blend-B	45.3
4	Blend-C	43.0
5	Blend-D	42.0
6	Blend-E	41.0
7	Blend-F	40.0
8	PPBD10	44.0
9	MBD10	43.5
10	PPBD20	43.2
11	MBD20	43.1
12	PPBD40	43.0
13	MBD40	42.5
14	PPBD60	42.0
15	MB60	41.5
16	PPB80	42.0
17	MBD80	41.5
18	PPBD	42.0
19	MBD	41.5
20	P0	42.0
21	M0	41.0

Canola oil directly in the ELSBETT Engine is suitable (feasible).

For the experimental study, Osama Ahmad Elsanusi *et al.,* employed the following supplies: pallets containing sodium hydroxide and methanol; low sulfur diesel that they bought from a nearby gas station; and canola oil that they bought from a nearby grocery[4]. For the experimental inquiry, a 2-cylinder, 4-stroke, air-cooled diesel engine with a DI system was utilized. The transesterification process is used to create the two bio-diesels (mustard oil and pongamia pinnata oil)[8]. The following amounts were used to create the dual bio-diesel blends:

The following characteristics of two bio-distillates, raw oils, blended mixes of bio-diesel, and their specific gravities, fire points, and flash points were

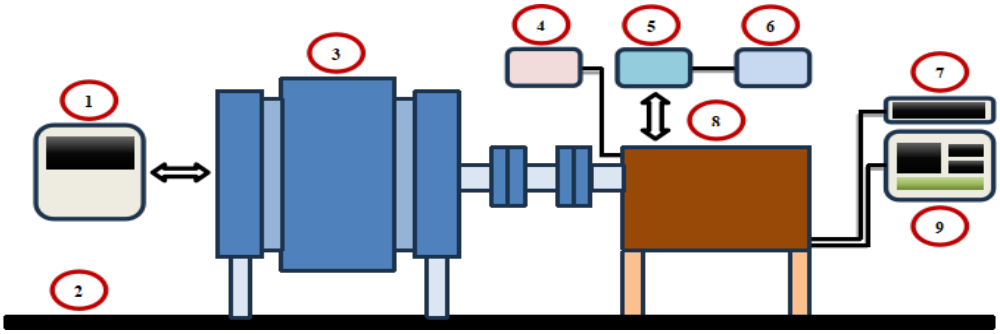


Figure 2. Experimental Set Up[1].
Engine Controller 2. Base 3. Eddy Current Dynamometer 4. Fuel Tank 5. Exhaust System 6. Calorimeter 7. Five Gas Analyzer 8. Single Cylinder Four Stroke DI Diesel Engine 9. Data Acquisition System

tested using ASTM procedures. Diesel properties were compared with the outcomes[8]. A number of biodiesel fuels' calorific values are shown in Table 1.

3.0 Critique

The qualities of bio-diesel were compared with base standard diesel fuel using a compression ignition engine[1]

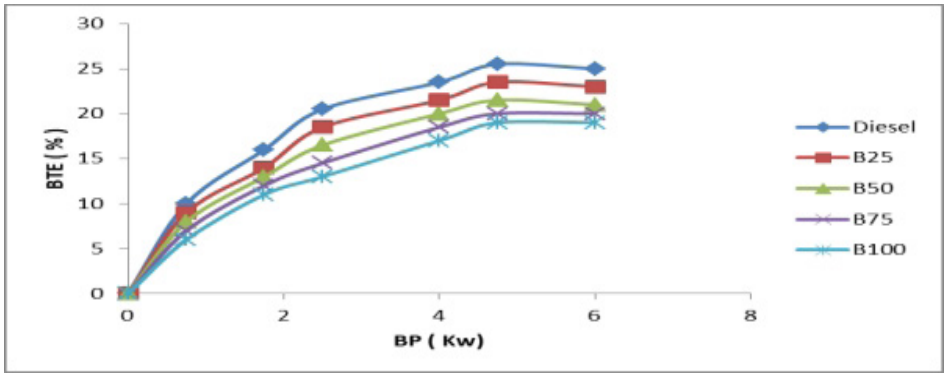


Figure 3. Graph of brake thermal efficiency TE Vs brake power[1].

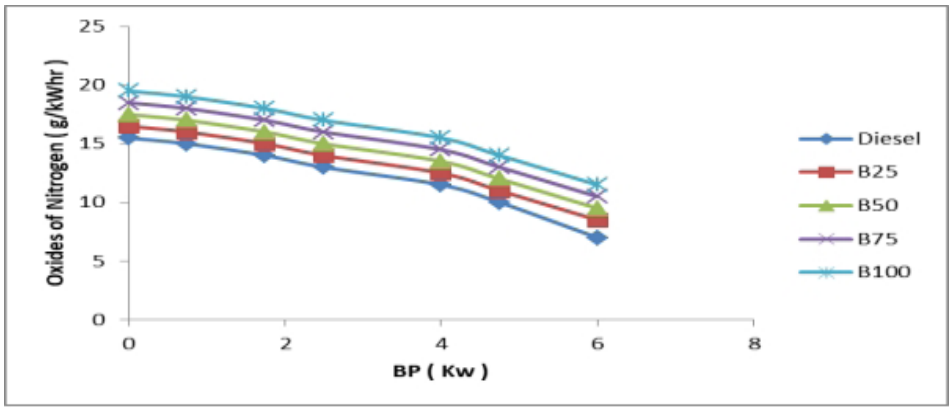


Figure 4. Graph of nitrogen oxide vs brake power[1].

with variable loads. Engines were tested using different non-edible rapeseed oils through the tans-esterification process. It compared the various efficiencies and pollutant gases % graphs of the engine running on rapeseed oil with that running on bio-diesel fuel. Figure 3 represents the graphical representation of Brake Thermal Efficiency [BTE] verses Brake Power (BP)[1].

A load test is performed to examine how a one cylinder CI engine performs under different loads while maintaining a constant speed of 1500 rpm. Additionally, plots of the various efficiencies and exhaust emission graphs were made; these are represented in Figures 3 and 4, respectively. For the experimental inquiry, a 2-cylinder, 4-stroke, air-cooled diesel engine with a DI system was utilized. In this study the performance and emission analysis of a stationary single cylinder engine has been carried out. In this study improvement in BTE was observed[1]. Also it was observed that NO_X and CO emissions were decreased by 2-3 % but no improvement in CO_2 and HC emissions were observed[1].

4.0 Result and Discussion

The test fuels are utilized in studies with compression ignition engines, and the results show how the Brake Thermal Efficiency (BTE) varies for various brake power ranges (Figure 3). The installed speed governor's self-governance keeps the engine rpm constant even when the engine is under increased load, resulting in a simultaneous increase in the engine's mass flow rate and brake power[1]. Together, these two elements increase the engine's thermal efficiency by lowering heat loss. Figure 4 represents the graph of Nitrogen oxide verses Brake Power [BP] Compared to an engine running on diesel, one powered by bio-diesel and its blends released less carbon monoxide and unburned hydrocarbons. Nitrogen oxide and smoke emissions increased (Figure 4).

Research revealed that as brake power increases, CO emissions drop. Under different load conditions, the B-20 blend's BSFC for beef tallow bio-diesel varies from 0.58 kg/kW-h to 0.28 kg/kW-h. When comparing the B-20 blend at 25% and 50% load, respectively, BTE ranges from 15.78% to 30.68%. Three engine speeds were selected for the experimental investigation: 1000 rpm, 2100 rpm, and 3000 rpm.

5.0 Conclusion

The following conclusions can be drawn from the experiment's results: The engine's braking thermal efficiency was lower while using bio-diesel and its blends than when using diesel fuel. When compared to other blends, the B-20 blend provided a slightly lower but still acceptable range of thermal efficiency when compared to base fuel i.e. diesel. Bio-diesel and blends of Bio-diesel affects the performance of compression Ignition Engine. It is observed that there was enhancement in Brake Thermal Efficiency and the fuel requirement was reduced by use of bio-diesel. Also the % of flue gases coming out from exhaust manifold of compression Ignition Engine was reduced by 3 to 7%.

The blends with BD-10 and BD-20 have the lowest BSFC values. Of all the mixes and pure diesel utilized in this investigation, the BD-20 blend has the highest mechanical efficiency. When BD-100 was compared to pure diesel, mechanical efficiency values were found to be 16.67% higher at nearly all of the brake power points.

- When BD-100 was compared to pure diesel, the BTE values were higher at all of the brake power points, and at a BP of 1.5282 Kw, the BTE increased by 17.5%.
- BD-10 and BD-20 were found to have the lowest HC emissions across the board under practically all load scenarios. At 60%, 80%, and 100% loads, pure bio-diesel (BD-100) produced less greenhouse gas emissions than pure diesel; however, at other loads, the opposite was true.
- There is a slight rise in BSFC, increase in mechanical efficiency, increase in BTE, and decrease in exhaust emissions when Canola bio-diesel is used. Therefore, the greatest alternative for the car industry is canola bio-diesel.
- An engine running on petroleum diesel has a continuous increase in BTE; on the other hand, an engine running on 20% bio-diesel derived from beef tallow oil experiences a decrease in BTE due to the bio-diesel's increased viscosity, density, low CV (Calorific Value), high volatility, and inadequate spray characteristics. This loss has been compensated for in the mix B-20 by the use of BHA (Butylated Hydroxy Anisole).

- CO emissions reduced by 27.9 % with use of blend B-20 without antioxidant additives.
- In one of the study better results were found at compression ratio of 18, NO_X was decreased and CO was increased. But in the same study at compression ratio of 14, CO was decreased.

6.0 Future Scope

An important consideration that has a direct impact on the engine's performance when using blends of biodiesel, additive, and diesel is the choice of compression ratio. The following aspects of biodiesel/additive/diesel mixes can be the subject of future research.

- Using various additives in biodiesel blends to lower the engine's compression ratio.
- Developing various ingredient blends to enhance diesel engine performance and lower hazardous emissions.
- Researching the biodiesel blends' vibration and noise characteristics.
- Using a four-stroke, multi-cylinder diesel engine to investigate the effects of bio-diesel blends.

7.0 Closing Statement

The efficiency and % of pollutant gases of a turbocharged DI diesel engine were evaluated by Alpaslan Atmanli *et al.*, at different engine speeds and under full load conditions using two different diesel fuels: vegetable oil-n-butanol ternary mixes. It demonstrates how, as load increases, the brake specific fuel consumption decreases until it reaches 60%. Greater B40 and B50 blends have higher brake specific fuel consumption; B50 blends have the highest brake specific fuel consumption. First, the Brake Specific Fuel Consumption falls with increasing load. However, when the load increases, the Brake Specific Fuel Consumption rises once more. B 30 has the lowest fuel usage (0.23 kg/kWh) when it comes to brakes specifically.

It was demonstrated that with greater blends of B-40 and B-50, thermal efficiency fell as the blending % increased. When the engine runs on a B-30 blend, less fuel is used expressly for braking. Because animal fat bio-diesel has a lower heating value and a greater oxygen percentage, more volumetric fuel must be consumed to keep the engine operating at the same energy input, which leads to complete oxidation[9]. The engine efficiencies were assessed using a number of factors, including thermal efficiency, specific fuel consumption, and exhaust gas temperature. Investigations were conducted into the thermodynamic characteristics of PPO and MO dual bio-diesels, as well as their blends[8].

Biodiesels have a considerably higher heating value than raw vegetable oil after the trans-esterification process. Raw vegetable oil has a lower heating value than diesel. The pongania pinnata ethyl ester has a higher heating value than the mustard oil ethyl ester. The Heating values of Blend-A and Blend-B are higher than single biodiesel blends because dual biodiesels and diesel are blended, making them comparable to diesel[8].

8.0 Corresponding Author Designation

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9.0 References

1. Raman LA, Deepanraj B, Rajakumar S, Sivasubramanian V. Experimental investigation on performance, combustion and emission analysis of a direct injection diesel engine fuelled with rapeseed oil biodiesel. Fuel. 2019; 246:69-74. https://doi.org/10.1016/j.fuel.2019.02.106
2. Subramaniam M, Solomon JM, Nadanakumar V, Anaimuthu S, Sathyamurthy R. Experimental investigation on performance, combustion and emission characteristics of DI diesel engine using algae as a biodiesel. Energy Reports. 2020; 6:1382-92. https://doi.org/10.1016/j.egyr.2020.05.022
3. Nagappan B, Devarajan Y, Kariappan E, Philip SB, Gautam S. Influence of antioxidant additives on performance and emission characteristics of beef tallow biodiesel-fuelled CI engine. Environ Sci Pollut Res. 2021; 28:12041-55. https://doi.org/10.1007/s11356-020-09065-9 PMid:32410194
4. Elsanusi OA, Roy MM, Sidhu MS. Experimental investigation on a diesel engine fueled by diesel-biodiesel blends and their emulsions at various engine operating conditions. Appl Energy. 2017; 203:582-93. https://doi.org/10.1016/j.apenergy.2017.06.052

5. Atmanli A, Ileri E, Yüksel B. Experimental investigation of engine performance and exhaust emissions of a diesel engine fueled with diesel-n-butanol-vegetable oil blends. Energy Convers Manag. 2014; 81:312-21. https://doi.org/10.1016/j.enconman.2014.02.049
6. Mofijur M, Rasul M, Hassan NM, Uddin MN. Investigation of exhaust emissions from a stationary diesel engine fuelled with biodiesel. Energy Procedia. 2019; 160:791-7. https://doi.org/10.1016/j.egypro.2019.02.159
7. Srithar K, Balasubramanian KA, Pavendan V, Kumar BA. Experimental investigations on mixing of two biodiesels blended with diesel as alternative fuel for diesel engines. J King Saud Univ Eng Sci. 2017; 29(1):50-6. https://doi.org/10.1016/j.jksues.2014.04.008
8. Nayak SK, Pattanaik BP. Experimental investigation on performance and emission characteristics of a diesel engine fuelled with mahua biodiesel using additive. Energy Procedia. 2014; 54:569-79. https://doi.org/10.1016/j.egypro.2014.07.298
9. Shahir VK, Jawahar CP, Suresh PR, Vinod V. Experimental investigation on performance and emission characteristics of a common rail direct Injection Engine using animal fat biodiesel blends. Energy Procedia. 2017; 117:283-90. https://doi.org/10.1016/j.egypro.2017.05.133
10. Jain M, Mishra B, Pal A. Performance and Emission Analysis of a Diesel Engine Using Thumba Oil bio-diesel. 2nd International Reference; 2015.
11. Jain NL, Soni SL, Poonia MP, Sharma D, Srivastava AK, Jain H. A durability study of a compression ignition engine operating with Thumba (*Citrullus colocyntis*) vegetable oil. Environ Sci Pollut Res. 2019; 26:8992-9004. https://doi.org/10.1007/s11356-019-04237-8 PMid:30715705
12. Srivastava AK, Soni SL, Sharma D, Sonar D, Jain NL. Effect of compression ratio on performance, emission and combustion characteristics of diesel-acetylene-fuelled single-cylinder stationary CI engine. Clean Technol Environ Policy. 2017; 19:1361-72. https://doi.org/10.1007/s10098-017-1334-0
13. Mata TM, Igor RBGS, Vieira SS, Caetano NS. Bio-diesel production from corn oil via enzymatic catalysis with ethanol. Energ Fuel. 2012; 26(5):3034-3041. https://doi.org/10.1021/ef300319f
14. Wu Q, Xie X, Wang Y, Roskilly T. Effect of carbon coated aluminum nanoparticles as additive to biodiesel-diesel blends on performance and emission characteristics of diesel engine. Appl Energy. 2018; 221:597-604. https://doi.org/10.1016/j.apenergy.2018.03.157
15. Hoang AT. A design and fabrication of heat exchanger for recovering exhaust gas energy from small diesel engine fueled with preheated bio-oils. Int J Appl Eng Res. 2018; 13(7):5538-45.
16. Srithar K, Balasubramanian KA, Pavendan V, Kumar BA. Experimental investigations on mixing of two biodiesels blended with diesel as alternative fuel for diesel engines. J King Saud Univ Eng Sci. 2017; 29(1):50-6. https://doi.org/10.1016/j.jksues.2014.04.008
17. Singh A, Sinha S, Choudhary AK, Sharma D, Panchal H, Sadasivuni KK. An experimental investigation of emission performance of heterogeneous catalyst jatropha biodiesel using RSM. Case Stud Therm Eng. 2021; 25:100876. https://doi.org/10.1016/j.csite.2021.100876
18. Aydın H. Scrutinizing the combustion, performance and emissions of safflower biodiesel-kerosene fueled diesel engine used as power source for a generator. Energy Convers Manag. 2016; 117:400-9. https://doi.org/10.1016/j.enconman.2016.03.046
19. Shaafi T, Velraj RJ. Influence of alumina nanoparticles, ethanol and isopropanol blend as additive with diesel-soybean biodiesel blend fuel: Combustion, engine performance and emissions. Renew Energy. 2015; 80:655-63. https://doi.org/10.1016/j.renene.2015.02.042
20. Debbarma S, Das B, Roy B. Experimental investigation of engine performance of Neem-Karanja mixed biodiesel blend in a CI engine. In AIP conference proceedings. AIP Publishing; 2018. https://doi.org/10.1063/1.5049098
21. Balaji G, Cheralathan M. Experimental investigation of antioxidant effect on oxidation stability and emissions in a methyl ester of neem oil fueled DI diesel engine. Renew Energy. 2015; 74:910-6. https://doi.org/10.1016/j.renene.2014.09.019
22. Nair JN, Kaviti AK, Daram AK. Analysis of performance and emission on compression ignition engine fuelled with blends of neem biodiesel. Egypt J Pet. 2017; 26(4):927-31. https://doi.org/10.1016/j.ejpe.2016.09.005
23. Ali MH, Mashud M, Rubel MR, Ahmad RH. Biodiesel from Neem oil as an alternative fuel for Diesel engine. Procedia Eng. 2013; 56:625-30. https://doi.org/10.1016/j.proeng.2013.03.169
24. Khan MM, Sharma RP, Kadian AK, Hasnain SM. An assessment of alcohol inclusion in various combinations of biodiesel-diesel on the performance and exhaust emission of modern-day compression ignition engines-a

review. Mater Sci Energy Technol. 2022; 5:81-98. https://doi.org/10.1016/j.mset.2021.12.004
25. Nithyananda BS, Anand A, Prakash GVN. Performance study on diesel engine using different blends of neem biodiesel. Int J Eng Res Appl. 2013; 3(4):1778-81.
26. Kumar KD, Kumar PR. Experimental investigation of cotton seed oil and neem methyl esters as biodiesel on CI engine. International Journal of Modern Engineering Research (IJMER). 2012; 2(4):1741-6.
27. Anbumani K, Singh AP. Performance of mustard and neem oil blends with diesel fuel in CI engine. Carbon. 2006; 86(78):92.
28. Stroke F. Corrosion and engine test analysis of neem (*Azadirachta indica*) oil blends in a single cylinder, four stroke, and air-cooled compression ignition engine. Am J Mech Eng. 2014; 2(6):151-8. https://doi.org/10.12691/ajme-2-6-1
29. Tamboli Y, Selokar GR, Paul A, Zala J. Feasibility testing of VCR engine using various blend of Neem oil. Int J Innov Res Sci Eng Technol. 2013 Jun; 2:170-82.
30. Mall AP. Performance and emission testing of neem oil methyl ester (Biodiésel). Internal Combustion Engine. International Journal of Innovative Research in Science, Engineering and Technology. 2015; 4(11):11101-11.
31. Sivalakshmi S, Balusamyb T. Experimental investigation on a diesel engine using neem oil and its methyl ester. Thermal Science. 2011; 15(4):1193-204. https://doi.org/10.2298/TSCI100810054S
32. Shrivastava N, Sungra T. A study to investigate the effect of diethyl ether as additive on the performance and emissions of engine using diesel and Neem oil methyl ester as fuel. Int J Renew Energy Res. 2018; 8(2):888-94.
33. Konada NK, Suma KN, Kumar BA. Experimental investigation on performance, smoke and exhaust gas analysis of four stroke diesel engine using pongomia/neem oil biodiesel. Int J Eng Sci Technol. 2020; 12(4):23-40. https://doi.org/10.4314/ijest.v12i4.3
34. Balaji G, Cheralathan M. Experimental investigation of varying the fuel injection pressure in a direct injection diesel engine fuelled with methyl ester of neem oil. Int J Ambient Energy. 2017; 38(4):356-64. https://doi.org/10.1080/01430750.2015.1111846
35. T. Thirumalai, M. Prakashbabu, A. Reddy HV, Reddy MR, Raj Kumar A. Performance of bio-diesel Fuel and neem oil blends in single cylinder diesel engine. Int J Eng Adv Technol. 2019; 9(2). https://doi.org/10.35940/ijeat.B3871.129219
36. Khan TY. Direct transesterification for biodiesel production and testing the engine for performance and emissions run on biodiesel-diesel-nano blends. Nanomaterials. 2021; 11(2):417. https://doi.org/10.3390/nano11020417 PMid:33562116 PMCid:PMC7915336
37. Sharma D, Soni SL, Mathur J. Emission reduction in a direct injection diesel engine fueled by neem-diesel blend. Energy Sources, Part A. 2009; 31(6):500-8. https://doi.org/10.1080/15567030701715542
38. Sundaram M, Balan KN, Arunkumar T, Ganesan S, Rameshbabu A. Emission study on the outcome of DMC on neem bio-diesel-ignited diesel engine. Energy Sources, Part A Recover Util Environ Eff. 2019:1-0. https://doi.org/10.1080/15567036.2019.1691683
39. Ganesan N, Masimalai S. Experimental investigation on a performance and emission characteristics of single cylinder diesel engine powered by waste orange peel oil biodiesel blended with antioxidant additive. Energy Sources A: Recovery Util Environ Eff. 2020; 42(11):1412-23. https://doi.org/10.1080/15567036.2019.1604856
40. Henni MH, Saïdia LM, Muthanna BGN, Mohamad AT, Sidik NAC. Experimental evaluation of the performance of a diesel engine feeding with ethanol/diesel and methanol/diesel. J Adv Res Fluid Mech Therm. 2024; 15(1):14-27. https://doi.org/10.37934/arefmht.15.1.1427
41. More GV, Rao YVH, Prasad PI, Sangapillai K. Characterization of biodiesel blends produced from repurpose used cooking oil. Int J Ambient Energy. 2024 Dec 31; 45(1):2367738. https://doi.org/10.1080/01430750.2024.2367738
42. More GV, Koli SR, Rao YH, Prasad PI, Rao BN. Effect of compression ratio on compression ignition engine with RUCO biodiesel/diethyl ether/diesel fuel blends. Energy Sources A: Recovery Util Environ Eff. 2020:1-20. https://doi.org/10.1080/15567036.2020.1785593
43. More GV, Rao YV, Prasad PI, Rao BN. Experimental investigation on the effect of compression ratio over emission and performance characteristics of the diesel engine using ternary blends. Int J Green Energy. 2021; 18(3):231-42. https://doi.org/10.1080/15435075.2020.1854263
44. Alahmer A, Alahmer H, Handam A, Rezk H. Environmental assessment of a diesel engine fueled with various biodiesel blends: Polynomial regression and grey wolf optimization. Sustainability. 2022; 14(3):1367. https://doi.org/10.3390/su14031367
45. More GV, Rao YV. Thermogravimetric study and combustion characteristics of biodiesel blends produced

from repurpose used cooking oil. Int J Environ Sci Technol. 2022; 19(7):6847-62. https://doi.org/10.1007/s13762-021-03474-0

46. More GV, Hanumantha Rao YV, Kedar SA, Gawande SH. Biodiesel production from DK oils using Taguchi L9 techniques: characterization and thermogravimetric study of combustion characteristics. J Therm Anal Calorim. 2022; 147(12):7043-62. https://doi.org/10.1007/s10973-021-11020-w

Nomenclature

HC- Hydro Carbon

CO- Carbon Monoxide

PM- Particulate Matter

NO_x- Nitrogen Oxides

BD- Bio-Diesel

BD-10- 10% bio-diesel + 90% diesel

BD-20- 20% bio-diesel + 80% diesel

BD-30- 30% bio-diesel + 70% diesel

BD-40- 40% bio-diesel + 60% diesel

BD-50- 50% bio-diesel + 50% diesel

BD-100- 100% bio-diesel