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A Systematic Study on Performance and Emission Characteristics of CI Engine Using Microalgae Methyl Ester with Nano Additives

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Abstract- India is looking at renewable alternative fuel sources to reduce its dependence on foreign crude oil. As India imports 80% of the oil it uses, it has been hit hard by increasing costs and uncertainty. In this study, microalgae biodiesel have been proposed as an alternative fuel for powering existing diesel engine. The present study is proposed to investigate experimentally, the performance and emission analysis of microalgae biodiesel in a stationary single-cylinder VCR diesel engine and compare it with diesel fuel. The microalgae biodiesel will be blended with the diesel fuel in different proportions. The brake thermal efficiency (BTE), brake power (BP), brake specific fuel consumption (BSFC), and brake mean effective pressure (BMEP) will be measured for different blends at a constant speed and various loads. Separate tests will be conducted for pure diesel and biodiesel blends. A comparative study will be carried out based on different performance and emission curves. Performance and emission analysis will be done for different blends with nanoparticles as additives and pure diesel at various loads and constant speed. The impact of nanoparticles blended microalgae biodiesel on the performance and emission of a diesel engine will be investigated. 10 %, 15%, and 20% Biodiesel with nanoparticles such as Al_2O_3, CuO, and CNT will be used as fuel for the experiment. This fuel will be examined with varying loads and the obtained results of performance and emission characteristics will be compared to that of 100% diesel. By doing a stagnant analysis it concludes that very few researchers have opened their eye towards the use of microalgae fuel with nano additives and tried its performance and emission analysis on a computerized setup

Index Terms- Methyl Ester, Microalgae, CI Engine, Nano additives, etc

I. Introduction

Biodiesel refers to a vegetable oil- or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, ethyl, or propyl) esters. Biodiesel is typically made by chemically reacting lipids (e.g., vegetable oil, soybean oil, animal fat (tallow) with an alcohol producing fatty acid esters. There has been plenty of research done so for on emission testing and biodiesel production. Research in the area of biodiesel has shifted towards making it more economically feasible by lowering production costs and increasing the energetic yields from the various feedstock. Where the research has lacked is about the better characterization of the performance of these fuels in all possible diesel applications. The goal of this work is to determine the usefulness of biodiesel in a single-cylinder diesel engine. So our aim of the study is mainly to conduct engine testing to evaluate performance, emission, and combustion characteristics. In the present study, the tests will be carried out at different loads, at a constant speed without any engine modification. The effect of different blends on brake thermal efficiency, brake power, brake specific fuel consumption, and on brake mean effective pressure will be studied.

II. LITERATURE SURVEY

[1]The paper of 'Prafulla D. Patil, Shuguang Deng' titled 'Optimization of biodiesel production from edible and non-edible vegetable oils.' in 2009 states that Two-step and one-step transesterification methods are best suitable for non-edible oils and edible oils, respectively for the production of biodiesel. Further research and development on some advanced methods such as supercritical methanol process, in situ alkaline transesterification, and microwave method, is necessary. The kinetic study, long-term run, and analysis using biodiesel fueled engine are also recommended. [2] 'A. Murugesan, C. Umarani, T.R. Chinnusamy, M. Krishnan, R. Subramanian, N. Neduzchezha in' with the title 'Production and analysis of biodiesel from non-edible oils: A review' stated that As per the analytical method reported in literature high-performance liquid chromatography method is suitable to analyze the reaction intermediates and products of transesterification reaction. Economic feasibility study shows that the bio-diesel obtained from non-

edible oil is cheaper than that from edible oils. [3] In the paper of 'Hwanam Kim, Byungchul Choi' with the title of 'The effect of biodiesel and bioethanol blended diesel fuel on nanoparticles and exhaust emissions from CRDI diesel engine' talk about The engine performance under biofuel-blended diesel fuels was similar to that under D100 fuel; the slightly higher fuel consumption was due to the lower calorific value that was based on the biofuel mixture. The use of biodiesel– diesel blends reduced the THC and CO emissions but increased NOx emissions, as the oxygen content of the fuel increased. Smoke emissions were reduced by 50% with the use of bioethanol-diesel blends. [4] 'A.E. Atabani, A. S. Silicon, H. C. Ong, T. M. I. Mahli, H. H. Masjuki, Irfan Anjum Badruddin, H. Fayaz' With the name of paper 'Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production' talk about the Production of biodiesel from non-edible oil resources can play a vital role in helping to overcome the land problem as it can be grown in marginal and wasteland areas for high yield. Moreover, the issue of food versus fuel for edible oil sources will make non-edible oil feedstocks as alternative fuels for diesel engines. Therefore, the demand for non-edible oil sources is expected to increase sharply shortly. Some non-edible feedstock for biodiesel production includes Jatropha curcas, Pongamia pinnata, Rubberseed, Madhuca indica, Calophyllum in the phylum, Sterculia feotida, etc. However, it must be pointed out that global biodiesel feedstock should not rely on certain sources as it could bring harmful influence in the long run. [5] 'A.S. Silitong, H. H. Masjuki, and et al' said in their paper with the title 'Overview properties of biodiesel diesel blends from edible and non-edible feedstock' said that Biodiesel can be considered as feasible alternative substitution fuel for a diesel engine without any modification. Thebiodiesel enrichment caused an increase in viscosity and reduces the volatility of the blends. Further study on the utilization of biodiesel in diesel engines needs to be carried out to assure optimization in engine operation.

[6] 'J. Sadik Basha, R.B. Anand' said in the paper of title 'Performance, emission and combustion characteristics of a diesel engine using Carbon Nanotubes blended Jatropha Methyl Ester emulsions' that The CNT blended emulsions have potential advantages on improving the performance and reducing the emissions from the diesel engine. Critical investigations are also in progress to trap the possible unburnt CNT from the exhaust of the diesel engine to safeguard the global environment. [7] 'V. Arul Mozhi Selvan, R.B. Anand, M. Udayakumar' in their paper 'Effect of Cerium Oxide Nanoparticles and Carbon Nanotubes as fuel-borne additives in Diesterol blends on the performance, combustion, and emission characteristics of a variable compression ratio engine' talk about The combined effect of CERIA and CNT as fuel- borne nanoparticles additives in the Diesterol fuel blend contributes for the cleaner combustion and significantly reduces the harmful exhaust gas emissions. [8] 'Ali M.A. Attia, Ahmed I. El-Seedy, Hesham M. El-Batsh, & et al' said that The use of biodiesel- diesel mixture leads to a slight decrease in the engine thermal efficiency and so an increase in BSCF. Exhaust gas temperature is reduced as the nano additive concentration is increased no matter the engine speed in their paper of title 'Effects of Alumina Nanoparticles Additives into Jojoba Methyl Ester-Diesel Mixture On Diesel Engine Performance' [9] In the title of paper 'Effects of alumina nanoparticles in waste chicken fat biodiesel on the operating characteristics of a compression ignition engine' by 'Naresh Kumar Gurusala V Arul Mozhi Selvan' said that The BSFC for all the WCFME diesel fuel blends were found higher when compared to the neat diesel due to lower calorific value of the biodiesel blends. The BTE increases when the alumina nanoparticles concentration in the fuel blend increases due to the better combustion characteristics of the nano-fuel blends. The carbon monoxide and hydrocarbon emissions were lower for the WCFME-diesel fuel blends when compared with the diesel. The NO emissions were slightly increased with the increasing alumina concentration due to the higher combustion pressure and temperature of the fuel blends. The smoke emissions were found lower about 65 % when using the alumina nanoparticles compared to the neat diesel. [10] 'Mehrdad Mirzajanzade h, Meisam Tabatabaei, & et al' in their research work title as 'A novel soluble nanocatalysts in diesel– biodiesel fuel blends to improve diesel engines performance and reduce exhaust emissions' reported that All pollutants i.e., NOx, CO, HC, and soot were reduced by up to 18.9%, 38.8%, 71.4%, and 26.3%, respectively, in B20 (90 ppm) compared to neat B20. The innovated fuel blend also increased engine performance parameters i.e. power and torque by up to 7.81%, 4.91%, respectively, and decreased fuel consumption by 4.50%.

[11] 'C. Syed Aalam, C.G. Saravanan' in their paper talk about Brake thermal efficiency (BTE) increases with the load for both Mahua biodiesel blend (MME20) and ANP- blended MME20. Significant reduction in HC emissions when replacing diesel fuel with biodiesel addition of aluminum oxide nanoparticles reduces the hydrocarbon emissions because ANP supplies the oxygen for the oxidation of hydrocarbon and CO during combustion with the title as 'Effects of nanometal oxide blended Mahua biodiesel on CRDI diesel engine' [12] In the year of 2015 'A. Prabu, R.B. Anand' studied the For JBD30A30C test fuel, higher brake thermal efficiency of 31% is observed, which is almost near to the brake thermal efficiency of neat diesel by 32 %. A significant percentage reduction of NO by 13 %, CO by 60 %, Unburned HC by 33 % and smoke emission by 32 % are observed for JBD30A30C test fuel compared to neat biodiesel. Hence, the nanoparticle addition to neat biodiesel will be a promising technique for increasing the performance and reducing the emission characteristics of the engine, without any engine modifications in their research work of title as 'Emission control strategy by adding alumina and cerium oxide nanoparticle in biodiesel' [13] In the title 'Experimental investigation on the effects of Cerium oxide nanoparticle on Calophyllum inophyllum (PUNNAI) biodiesel blended with diesel fuel in DI diesel engine modified by nozzle geometry' of 'G. Vairamuthu, S. Sundarapand Ian & et al' reported that The CON acts to burn- off the carbon deposits within the engine cylinder at the wall temperature and prevents the deposition of non-polar compounds on the cylinder wall which resulting in the reduction of hydrocarbon emissions. In addition, it is apparent that the CON added beyond 40ppm to the fuel increase the fluid layer resistance and hence, increases the viscosity. The change in the viscosity of the fuel affects the engine performance as well as the hydrocarbon emissions. [14] The brake specific energy consumption is higher for the B20 and D80SBD15E4S1+alumina fuel blends compared to neat diesel at 25% and 50% load. There is a considerable reduction in the major pollutants such as CO, CO2, UBHC in the case of D80SBD15E4S1+alumina fuel blend, compared to neat

diesel at the full load condition, due to the inherent oxygen present in the soybean biodiesel, as it is better utilized by the presence of the alumina nanoparticle was discussed by 'T. Shaafi, R. Velraj' in the research topic as 'Influence of alumina nanoparticles, ethanol and isopropanol blend as additive with diesel soybean biodiesel blend fuel: Combustion, engine performance and emissions' [15] During 2015 'Srinivasa Rao, M. and Anand, R. B.' publish a research work in the area of methyl ester name as 'Performance and emission characteristics improvement studies on a biodiesel fuelled DICI engine using water and AlO(OH) nanoparticles' had studied that The performance of the engine, when BD10W100 is used as fuel, is almost close to neat diesel and CO, UHC, NO and smoke opacity emissions are reduced by 50, 39, 37 and 25 % for BD10W100 fuel compared to neat diesel. NO and smoke opacity are reduced by 42 % and 18 % respectively for BD10W100 fuel compared to biodiesel. BTE is improved by 6 % and emission reduction NO by 27 % and smoke opacity by 8 % for BD10W fuel compared to biodiesel.

[16] Some scholars 'C. Syed Aalam, C.G. Saravanan, M. Kannan' works in the title of paper 'Experimental investigations on a CRDI system assisted diesel engine fuelled with aluminium oxide nanoparticles blended biodiesel' come to conclusion that The aluminium oxide nanoparticles (Al2O3) are efficient in improving the properties of biodiesel blend. It also enhances the performance and reduces the emission of biodiesel blend used in the diesel engine. For a possible solution to the increase in the NOx emission, new, modified injection strategies with multiple injection events have to be considered. Further developments are in progress to minimize the unborn AONP from the exhaust. [17] 'Soner Gumus, Hakan Ozcan, Mustafa Ozbey, Bahattin Topaloglu' studied in the year 2016 and come to the conclusion that Emissions of CO, HC and NOx with the addition of Al2O3 to neat diesel are significantly lower with up to 11%, 13% and 6%, respectively. Emissions of CO, HC and NOx with the addition of CuO to neat diesel are lower with up to 5%, 8% and 2%, respectively. CuO and Al2O3 additives led to a reduction in BSFC of up to 0.5% and 1.2% at moderate engine speed,respectively in the title 'Aluminum oxide and copper oxide nanodiesel fuel properties and usage in a compression ignition engine.' [18] In the title of research work 'Effect of a zinc oxide nanoparticle fuel additive on the emission reduction of a hydrogen dual- fuelled engine with Jatropha methyl ester biodiesel blends.' by 'Syed Javed, Y. V. V. Satyanarayan a Murthy, M. R. S. Satyanarayan a, Rajeswara Reddy R1, K. Rajagopal' said that NOx emissions are reduced with the inclusion of nanoparticles. HC emissions mainly depend on nanoparticle size and H2 flow rates. With the presence of ZnO nanoparticles in blends of pure JME, the CO emission increased, and higher H2 flow rate supplemented the CO emission. [19] 'Harish Venu, Venkatarama nan Madhavan' studied that Advancing the injection timing with Al2O3 addition resulted in higher cylinder pressure and heat release rate nearer to TDC. Higher combustion duration, lower ignition delay and lowest BSFC were also observed. Emission wise, Al2O3 addition at ADV IT resulted in higher HC, CO and NOx with lowered smoke and CO2 emissions. Retarding the injection timing with Al2O3 addition resulted in lowered cylinder pressure and heat release rate occurs away from TDC. Lower combustion duration, BSFC and higher ignition delay were also observed. Emission wise, Al2O3 addition at RET IT resulted in lowered HC, CO, CO2, NOx and smoke emissions with higher EGO in the title 'Effect of Al2O3 nanoparticles in biodiesel diesel- ethanol blends at various injection strategies: Performance, combustion and emission characteristics.' [20] In the paper of 'Hariram Venkatesan, Seralathan Sivamani, Srinivasan Sampath, Gopi V, Dinesh Kumar M' with title 'A Comprehensive Review on the Effect of Nano Metallic Additives on Fuel Properties, Engine Performance and Emission Characteristics' talk about the Addition of nanoparticles plays a major role in improving the fuel properties and enhancing the performance of CI engine as well as reducing the exhaust emissions. Addition of nanoparticles increases BTE which depends upon the base fuel used, amount of nanoparticle added, how well they are mixed with the base fuel, and operating condition of the CI engine. Nanoparticles like Al2O3, Al, CNT and CeO2 shows good results as additives with diesel and biodiesel blends in all aspects. ZnO also gives better results but, more amount of ZnO should be added than other nanoparticles to get an equivalent performance and the use of ZnO as fuel additive increases the cost of fuel.

[21] In the year of 2017 'Vishal Saxena, Niraj Kumar, Vinod. Kumar Saxena' done a research and come to the conclusion that It was also suggested that improving engine design through additional swirling effect produced by providing slots on the piton or by changing the injector nozzle geometry (increasing number of holes in a nozzle) gives high injection pressure, which reduces the fuel droplet diameter and maintains better spray patterns. Besides this the fast vaporization of fuel inside the cylinder promotes complete combustion of fuel which results in higher engine efficiencies and lower specific fuel consumption with reduced emission levels in the title 'A comprehensive review on combustion and stability aspects of metal nanoparticles and its additive effect on diesel and biodiesel fuelled C.I. engine' [22] Chiranjeeva Rao Seela, B. Ravisankar & et al reported in their title 'A GRNN based frame work to test the influence of nano zinc additive biodiesel blends on CI engine performance and emissions' that The BTE is 2–3% more with the B20 added with 50 and 100 ppm of ZnO Compared to the diesel fuel. The fuel B20 with 50 ppm ZnO has given lower NOx emission compared to all tested fuels including diesel. The deviation of BTE, sfc, NOx, HC, CO2 and CO is minimum with the smoothening factor of 4.4, 2.9, 1.2, 1.2, 1.2 and 2.3 respectively. [23] R.Sathiyamoort hi, G.Sankaranaray anan K. Pitchandi contributed in the research work and come to the discussion that The addition of the combined effect of nano- emulsified LGO25 with DEE and EGR mode results a decrease in the CO emission by 2.43% than LGO25. On the other hand, EGR mode increases CO emission slightly by 2.5% than nano emulsified LGO25. EGR involves the reduction of oxygen availability in the combustion

chamber which affects the conversion of CO to CO2. Overall, the application of EGR and the cerium oxide added LGO25 emulsified fuel blend showed a better performance and reduction in harmful gases from the single cylinder direct injection diesel engine with title of 'Combined effect of nanoemulsion and EGR on combustion and emission characteristics of neat lemongrass oil (LGO)-DEE diesel blend fueled diesel engine.' [24] 'S. Debbarma R. D. Misra' said in the title 'Effects of Iron Nanoparticles Blended Biodiesel on the Performance and Emission Characteristics of a Diesel Engine.' that Dosage of iron nanoparticle up to 75 ppm with biodiesel blend PB30 (blend of 30% biodiesel and 70% diesel) improves the performance along with reduction in CO and NOx emissions without any engine modifications. [25] 'D. Yuvarajan, M. Dinesh Babu, N. BeemKumar, P. Amith Kishore' studied in the title 'Experimental investigation on the influence of titanium dioxide nanofluid on emission pattern of biodiesel in a diesel engine.' That HC, CO and Smoke emissions for MOME, MOMET100 and MOMET200 is lesser than diesel at all working conditions owing to its inbuilt oxygen content. NOx emissions for MOME, MOMET100 and MOMET200 are higher than diesel at all working conditions owing to longer delay period of biodiesel causing higher fuel ignition temperature. The addition of TiO2 nanofluid in (base fuel) mustard oil methyl ester results in reduction in HC, CO and smoke emissions at all loads owing to its improved oxidation capability, enhanced thermal conductivity and the catalytic effect. NOx emissions for MOMET100 and MOMET200 are significantly reduced by adding TiO2 nanofluid to MOME owing to the combined effects of heat absorption by water molecules and reduction in ignition delay due to catalytic effect of nano fluids.

[26] 'Gnanasikama ni Balaji And Marimuthu Cheralathan' in the research title 'Influence Of Alumina Oxide Nanoparticles On The Performance And Emissions In A Methyl Ester Of Neem Oil Fuelled Direct Injection Diesel Engine' said that The brake thermal efficiency, increased by 4.23% and NO emissions, reduced by 7.81%for MENO+ALN200 blend compared to neat biodiesel. The NO, HC, CO, and smoke emissions were reduced by adding nano additive to the neat biodiesel. The performance parameters like brake thermalefficiency increased and brake specific fuel consumption decreased by adding nano additive. This nano addition is a simple and easy method for simultaneous performance improvement and NO reduction. [27] 'Anjuman Shaheen, Shazia Sultana, & et al' Said in the heading 'Assessing the Potential of Different Nano- composite (MgO, Al2O3-CaO and TiO2) for Efficient Conversion of Silybum eburneum Seed Oil to Liquid Biodiesel' that MgO showed the promising results; highest conversion efficiency was achieved 91%, using MgO followed by Al2O3-CaO and TiO2 at 0.1% catalysts loading. The optimized experimental variables were; alcohol oil molar ration (1:3), temperature (700 C), reaction time (3 hrs) and stirring rate (600 rpm) using reflux transesterification route. Considering the encouraging results and finding of this study Silybum ebruneum was strongly recommended as an economically feasible potential feedstock for biodiesel production as renewable energy on industrial scale.[28] In the year 2018 'I. Ors, S. Sarıkoc, A.E. Atabanic, S. Unalan, S.O. Akansu' do study on 'The effects on performance, combustion and emission characteristics of DICI engine fueled with TiO2 nanoparticles addition in diesel/biodiesel/n- butanol blends' and said that The nano-particle additive of TiO2 has not substantially affected the blends properties. n-butanol has strongly affected some of the important properties of fuel blends such as density,kinematic viscosity, pour point, cloud point, cold filter plugging point and flash point. Besides, n-butanol improved cold flow properties of fuel blends. The maximum brake engine torque and power values are recorded for all tested fuels at approximately 1400 rpm and 2800 rpm, respectively. The addition of TiO2 to B20(B20+TiO2) increased the engine brake torque and power for about 10.20% compared to B20 blend. In addition, brake engine torque and power for B20But10+TiO2 is approximately 9.74% higher than B20But10. The brake specific fuel consumption decreased 27.73% and 28.37%, respectively (Compared to B20 and B20But10). It can be concluded that the addition of TiO2 in the fuel blend has positively affected engine performance. [29] 'Varatharaju Perumal, M. Ilangkumara n' said in the title 'The influence of copper oxide nano particle added pongamia methyl ester biodiesel on the performance, combustion and emission of a diesel engine' that PME has performed inferior in fuel qualities regarding BTE and BSFC due to its lower calorific value. Catalytic behavior of CuO had improved the BTE and BSFC significantly while it was mixed with pongamia biodiesel. A significant reduction in greenhouse gases of CO, HC, NOx and smoke has been observed as experimental result. CuO act as a catalyst and oxygen booster when mixed with PME blend which enhances combustion characteristics and hence a considerable reduction in smoke and NOx emission takes place.

[30] In the year of 2019 'Felix Sebastian Hirnera, Joonsik Hwanga & et al' said the heading 'Nanostructure characterization of soot particles from biodiesel and diesel spray flame in a constant volume combustion chamber' that Hue analysis showed that level of soot was lower for biodiesel fuels and they showed faster oxidation process by shorter duration of visible flame luminosity. This is mainly attributed to lower equivalence ratio because of oxygen species in the fuel molecules. In addition to that, lower aromatic and sulfur content in biodiesel prevented formation of soot precursors. Primary soot particles from all test fuels got smaller as the injection pressure increased. The primary particle diameter at 120 MPa was smaller up to 2 nm than 40 MPa case. In terms of fuels, primary particle diameter was 1-2 nm smaller for biodiesel fuels than that of diesel. The nanostructure in primary particle showed changes among the different injection pressures from an ordered tendency at 40 MPa over a more disordered tendency at 80 MPa to a finally again ordered structure at 120 MPa. According to fuels, primary particles of biodiesel soot were characterized by shorter

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fringe length with lower fringe tortuosity and smaller fringe spacing than those of diesel soot. A correlation between the nanostructure parameters fringe length, tortuosity and fringe spacing for the early stage of oxidation, as present in this experiment, was found. The suggested correlation states that small fringe length in combination with low tortuosity values led to the smallest inter planar distances. Whereas short fringes with high tortuosity values were leading to the higher fringe distances.

III. Critical Discussion on Literature Review

- Pro Production methodology of biodiesel from edible and nonedible oils was explained and optimization is done by various researchers. They concluded that further research and development on some advanced methods such as super critical methanol process in situ alkaline transesterification and micro wave method is necessary. (1,2,4,)
- Biodiesel properties are analyzed by researchers and concluded that Biodiesel can be considered as feasible alternative substitution fuel for Diesel engine without any modification. (5)
- Further, many researchers added Nanoparticles in biodiesel blends to enhance properties to improve performance and reduce emissions of CI engine. They concluded that addition of nanoparticles plays a major role in improving the fuel properties and enhancing the performance of CI engine as well as reducing the exhaust emissions. (3,10,11,20,21,23,24,25,29,30)
- Many researchers used specific nanoparticles like CNT, Al2O3 etc. CNT as fuel borne nanoparticles additives in the diesterol fuel blend contributes for cleaner combustion and significantly reduces the harmful exhaust gas emissions. (6,7)
- CuO act as a catalyst and Oxygen booster when mixed with PME blend which enhances combustion characteristics and hence a considerable reduction in smoke and NOX emission takes place.
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- CuO act as a catalyst and Oxygen booster when mixed with PME blend which enhances combustion characteristics and hence a considerable reduction in smoke and NOX emission takes place.
- The addition of TiO2 nano fluid in base fuel mustard oil methyl ester results in reduction in HC, CO and smoke emissions as all loads owing to its improved oxidation capability, enhanced thermal conductivity and the catalytic effect (26). The calophyllum inophyllum methyl ester nano emissions are promising alternatives fuel for diesel engine for significant reductions in exhaust emissions and improved performances compared pure calophyllum inophyllum biodiesel without any major modifications (28).
- Microbial oils are of a biorenewable feedstock for biodiesel production without compromising food and water supply. Additionally, the microalgae could gain desirable properties for production of an ideal biodiesel (39). Advanced biofuels such as drop in microalgae, and electro biofuels have been extensively investigated as alternatives to conventional plant based biofuels.

IV. CONCLUSION

1. The important physical, chemical properties and parameters of microalgae oil and their blends can be determined.
2. Suitability of chosen oils as alternate fuels used in diesel engine can be examined by evaluating performance and emission parameters of diesel engine using various blends. The results can be compared with those of diesel.
3. The overall studies based on the production, blending, engine performance and exhaust emission of microalgae oil derived biodiesel can be carried out.
4. Emission and performance parameters can be evaluated and compared with those of diesel

Nomenclature

NO_X = OXIDES OF NITROGEN
UBHC = UNBURNED HYDROCARBONS
SO = SMOKE OPACITY
EGT = EXHAUST GAS TEMPERATURE SFC = SPECIFIC FUEL
BTE = BRAKE THERMAL EFFICIENCY
BMEP = BRAKE MEAN EFFECTIVE PRESSURE
HME100 = 100% HEMP METHYL ESTER AND 0% DIESEL
NME100 =100% NEEM METHYL ESTER AND 0% DIESEL
HME20 = 20% HEMP METHYL ESTER AND 80% DIESEL
NME20 = 20% NEEM METHYL ESTER AND 80% DIESEL

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