A Review Paper On

Performance of Computerised Single Cylinder CI Engine with Blends of Bio Diesel

Mr. B. Phanindra Kumar[1], Jyothish Kumar Ranjan[2], Nakkala Harish[3], Pagidi Kethan[4]

[1]Assistant Professor, Dept of Mechanical, Guru Nanak Institute of Technology, Hyderabad, Telangana
[2,3,4] Student, Department of Mechanical, Guru Nanak Institute of Technology, Hyderabad, Telangana

---***---

Abstract - A nation's economic progress is significantly influenced by the production of energy. Energy is the main source of electricity for the home, the commercial and manufacturing sectors, transportation, agriculture, and industry. The demand for diesel engines has shown two levels of uncertainty over the last 20 years. First, the cost of pure fossil fuels is out of control, and the wealth disparity between importing and exporting nations has grown. Compression ignition (CI) engines use biodiesel, gradually replacing non-renewable fossil fuels. In the presence of a catalyst, they interacted with alcohol. The main benefit of biodiesel is that it is based on renewable energy sources and causes less environmental harm. The results of various studies in the literature concluded that because biodiesel has a higher oxygen content, less aromatic compounds, and a lower compressibility than diesel, it performs better as an engine fuel than diesel in terms of unburned hydrocarbon, carbon monoxide, smoke, and NOx emissions. The primary goals of the research are to improve the overall performance of the single-cylinder, four-stroke compression ignition engine using biodiesel fueled by various blends of jatropha and palm oil in accordance with the trends and regulations currently in place in the internal combustion engine industries.

Key Words: Fuel, IC Engine, Performance, Emission.

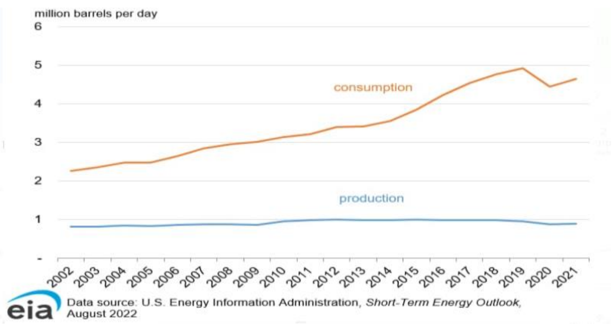
1.INTRODUCTION

1.1 Energy scenario

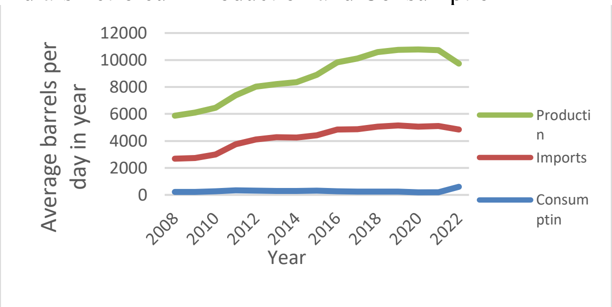
Energy generation has a significant role in a country's economic development. Agriculture, transportation, manufacturing, commercial, and home sectors rely on energy as a primary source of power. Since independence, a tremendous quantity of energy has been required to carry out India's economic development ambitions. As a result, energy demand is gradually increasing across the country. As there is increasing demand for oil and gas, there is the potential for an energy supply crisis resulting from sustained economic growth. Modernity and industrialization have led to significant increases in the demand for petroleum products around the world. Rapid economic growth in developing countries results in rising energy demand. The energy demand in India is growing at a rate of 6.5% per year over the next five years. Around 75-85 percent of the country's crude oil needs are met through imports from various countries. As a result, energy security has become a significant concern for the country as a whole. Petroleum-based fuels are insufficient, and limited reserves are concentrated in a few areas of the world (Jain & Sharma, 2010). Energy consumption is expected to exceed population increase by a large margin. By 2030, 39 percent of global greenhouse gas emissions and 31 percent of world energy demand are predicted, therefore developing a clean alternative to fossil fuels that is locally available, ecologically acceptable, and technically feasible has become a global goal.

1.2 Indian energy scenario

India's energy demand for petroleum-based products has been rapidly increasing. In March 2023, India, the world's third-largest oil consumer, was forecast to use 194.6 million tonnes of refined goods (Source: Petroleum Planning & Analysis cell, India). Moreover, it has had the second-largest increase in transport fuel use in India in the recent decade. In addition, because of the economic reforms, the manufacturing of road cars is predicted to expand, increasing gasoline demand. As a result, research into the patterns of gasoline demand in India is required. In addition, the ever-increasing number of automobiles with internal combustion engines is driving up energy demand. Energy is required for economic development, and financial growth is vital for developing countries. However, India has a far lower per capita energy use than developed countries. It is 4% of the US average and 20% of the global average. With India's growing economy, per capita 2 use is expected to rise. Energy demand in India is expected to rise from 100.432 metric tons (MT) in 2001-2002 to roughly 120.749 MT in 2006-2007, according to predictions and assessments in the 10th five-year plan. The proposed document estimates the compound annual growth rate (CAGR) to be 3.6 percent. Domestic crude oil production is planned to rise from 32.03 million tonnes in 2001-02 to 33.97 million tonnes by the end of the tenth plan period (2006-07). It should also be highlighted that India's oil self-efficiency has been steadily declining, from 60% in the 1950s to 30% now, with a further reduction to 8% by 2020. Imports are expected to meet 92 percent of India's total oil needs by 2020. The fact that non-renewable petroleum is finite and highly consumed, a loud warning that is paying attention to all nations. According to the Intergovernmental Panel on Climate Change (IPCC), global surface temperatures rise by 1.1°C to 6.4°C between 1990 and 2100 due to global warming. When fossil fuel reserves run out, and demand for energy rises, and an energy crisis emerges. Oil and coal provide the majority of the energy used by industries and transportation. Petroleum is a non-renewable and rapidly decreasing source of energy. The oil crisis of 1973 brought this issue to the forefront. Petroleum prices are constantly fluctuating, and most countries' costs are increasing. Global energy consumption is predicted to be 147 trillion kWh, with this figure expected to climb in the future. the production and consumption of India petroleum and other liquids from 200-2019. Crude oil imports have increased dramatically in recent decades.



India's Petroleum Production and Consumption

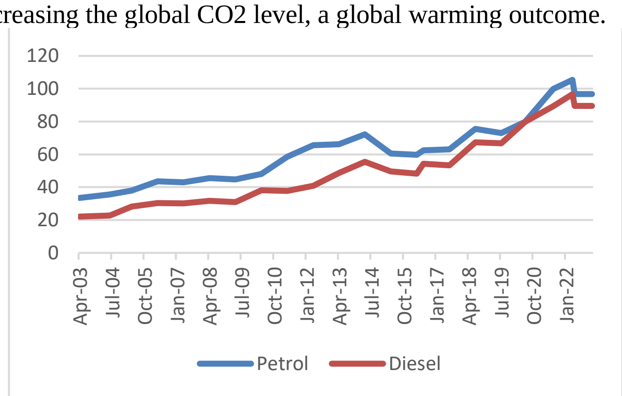


India Petroleum Production, Consumption and Imports

1.3 Problems of diesel engines

For the past two decades, the demand for diesel engines has revealed two levels of uncertainty. First, straight fossil fuel prices are too high, and importing nations' wealth has become more distressing. changes in petrol and diesel price per liter for the last 20 years in India. Over the years, the difference in petrol and diesel prices per liter has fallen, and still, a good chance is that gasoline and diesel will be price-close.

Secondly, fossil-fuelled combustion is the main factor in increasing the global CO2 level, a global warming outcome.



Price of Petrol Diesel From Last 20 Years

1.4 Alternate fuels

The primary motivation behind the search for fuel is that the shift to other fuels is free of stress due to crude oil deficits, which means that supply provides long-term security. Alternative fuels must meet the following criteria for selection: they must be both affordable and widely available. They should burn cleanly and emit fewer pollutants, as well as being simple and inexpensive to manufacture. They should also require a few changes to the current IC engines to extend the engine's life and reduce maintenance. Furthermore, they must be simple to treat and store. India currently imports more than 85% of its petroleum needs in 2019. This percentage of imports is likely to climb by further years. As a result, it is vital to switch from diesel to an alternative fuel.

1.5 Biodiesel as diesel engine fuel

Biodiesel is utilized in compression ignition (CI) engines, and non-renewable fossil fuels are eventually replaced. Diesel engines rely on animal fats, as well as edible and non-edible oils. Two significant factors have contributed in part to the use of animal fat and vegetable oil as fuel in diesel engines; low volatility and high viscosity, causing severe engine deposits, piston ring stick and input coking, prevented direct use of triglycerides in diesel engines (Singh & Singh, 2010). Biodiesel has a calorific value of 39 to 41 MJ/kg, significantly less than gasoline (46 MJ/kg). petrodiesel (43 MJ/kg) or petroleum (42 MJ/kg), but better than coal (32–37 MJ/kg) (Demirbas, 2007). The sulfur concentration of biodiesel, referred to as a neat fuel, is lower than that of petrodiesel. Biodiesel has excellent lubrication properties and is very biodegradable when used in CI engines. Many countries, including the United States of America, Malaysia, Brazil, France, Italy, Germany, Indonesia, and other European nations, have used biodiesel. Therefore, it could be used as a fuel alternative in CI engines. Before employing biofuel as an alternate fuel, it must meet the minimum requirements set forth by ASTM BS71-3 and EN14214. Cetane number, density, viscosity, cloud and pour points, flash point, ash content, distillation range, sulfur content, carbon deposit, acid value, and HHV are all characteristics of biodiesel fuels. Biodiesel fuel has been proven to have physical and chemical properties similar to and well suited to those of petrodiesel fuels. Its use in diesel engines has been found to boost engine performance while also lowering greenhouse gas emissions. The most significant benefit of using biodiesel in diesel engines is the reduction of gas emissions.

2. LITERATURE REVIEW

This situation initiated and sustained the interest in identifying renewable raw materials into alternative liquid fuels. Vegetable oil is not a new fuel for compression ignition engines as more than a hundred years ago, Rudolf Diesel tested his engine with vegetable oil as fuel (Chen Hu et al. [2]). In 1911 he stated that the diesel engine could be fed with vegetable oils and help 11 considerably develop the countries that use it. It has also reported that both edible and nonedible oils would be a promising alternative to diesel oil since they are renewable and can be produced easily in rural areas with an acute need for modern forms of energy (Babu et al., [3]). Biodiesel as alternative fuels Although diesel and gasoline are petroleum-based fuels, the usage of diesel engines is higher due to their higher efficiency compared to gasoline engines. The primary threat in the exploration of petroleum fuels is that it would decrease the petroleum reserves. In this context, renewable fuels would be a suitable alternative. Ethanol is well established as an alternative fuel for gasoline engines. Similarly, ongoing research studies proved that biodiesel fuels are better alternatives for diesel engines. Biodiesels derived from edible and non-edible oils or fats through a process called transesterification. These reacted with alcohol in the presence of a catalyst. The significant advantage of biodiesel is renewable energy-based sources, and it has a lower pollution impact on the environment. Biodiesel fuelled engines emit less CO, HC, and PM than diesel, increasing NOx emissions. (Joshi & Pegg [4]; Monyem & Van Gerpen [5]). The behaviour of biodiesel in diesel engines, such as atomization characteristics, physical and chemical ignition delay, heat release pattern, and other combustion transportation characteristics, is not similar to petroleum-based diesel fuel because of different chemical structure. As the chemical structure is different, both physical and chemical properties are different for diesel and biodiesel. The fuel properties such as viscosity, density, cetane number, and heating value significantly affect any diesel engine's combustion, performance, and emissions. For example, viscosity greatly affects the fuel atomization, and cetane number significantly affects the ignition quality. Several methods are available to modify the fuel properties. For example, blending with low viscous or pre-heating fuel reduces viscosity, adds cetane improvers to improve ignition quality, etc. In this context, alternate fuels with the suspension of nanometer-sized particles and antioxidants additives have been an important research area due to their enhanced thermophysical properties over petroleum-based fuels. 12 2.4 Effects of performance and emission parameters by use of biodiesel Previous studies conducted experimental and theoretical investigations in a diesel engine to study the alternate fuel for diesel. Palvannan et al. [1] investigated the effect of cashew nut biodiesel on a diesel engine. The performance results showed that BTHE of B20 fuel was equal to diesel as fuel, but further increase blend percentage shows the low BTHE value correlated to conventional diesel. The smoke and HC emissions reduced, but it increases NOx and carbon dioxide (CO2) emissions because of the complete combustion of biodiesel and high exhaust gas temperature (EGT). Renuraman et al. [2] examined Rice Bran Oil-Fueled IC Engine Performance and Emission Characteristics Improved by Nanoadditives. The BTHE value decreases with a higher percentage of blends because of the high viscosity of biodiesel. The BSFC, CO2, and NOx emissions increased by using biodiesel blend compared with conventional diesel because of the oxygen content of biodiesel, poor atomization of fuel, and higher combustion temperatures. Mahesh et al. [3] conducted the experiments using honge oil methyl ester (HOME) as fuel on a diesel engine. The performance results showed that BTHE and BSFC values increased because of the low calorific value correlated to diesel. The NOx emissions and EGT value increased because of the complete combustion of biodiesel. Sahoo et al. [4] examined the influence of Karanja, polanga, and jatropha biodiesel as fuels on a tractor engine. The emission results showed reduced HC and PM emissions because of the complete combustion. Still, it increased BSFC, CO, NOx emissions because of low calorific value (CV), biodiesel oxygen percentage, and high fuel viscosity. Abed et al. [5] investigated the effect of waste cooking-oil biodiesel on a diesel engine's performance and exhaust emissions. It reported low BTHE and higher BSFC and EGT obtained by biodiesel blends as correlated to convention diesel. The biodiesel blends produced less CO, HC, and other emissions except for NOx and CO2 emissions correlated to convention diesel. Uyumaz [6] studied the effects of combustion, performance, and emission characteristics of a direct injection (DI) diesel engine fueled with mustard oil biodiesel blends at different engine loads. It reported low BTHE and higher BSFC obtained by mustard biodiesel blends as correlated to convention diesel. The biodiesel blends produced less CO and smoke emissions except for NOx emissions as correlated to convention diesel. Shrivastava et al. [7] investigated the effects of engine performance and emission characteristics of CI engines operated with roselle and Karanja biodiesel. The results revealed reduced NOx and smoke emissions and increased BSFC and CO2 emissions obtained by roselle 13 biodiesel blends correlated to convention diesel. The results showed decreased BTHE, EGT, NOx, smoke emissions, and increased BSFC obtained by Karanja biodiesel blends correlated with convention diesel. Anantha Raman et al. [8] investigated the performance, combustion, and emission analysis of a direct injection diesel engine fuelled with rapeseed oil biodiesel. It reported low BTHE, heat release rate (HRR), maximum cylinder pressure, and higher BSFC and EGT obtained by biodiesel blends correlated to convention diesel. The biodiesel blends produced less CO and HC emissions except for NOx and smoke emissions correlated to convention diesel. Simsek [9] studied canola, sefflower oils, and waste oils as biodiesels on engine performance and exhaust emissions. The results revealed that BSFC and BTHE increased as the ratio of BD75 and decreased by 1.95% of BD correlated to diesel. Biodiesel blends produced less CO, HC, and smoke and increased NOx and CO2 emissions than conventional diesel. The literature findings on the CI engine's performance, combustion, and emission analysis by adding biodiesel as a fuel. Previous studies reported that biodiesel's use in diesel engines increases BSFC and lowers brake power (BP). The emissions of HC, CO, PM reduced, and NOx and CO2 emissions raised by biodiesel as fuel in diesel engines. Nanoparticles and antioxidants additives added with biodiesel blends overcome the drawbacks of biodiesel blends used as fuels on a diesel engine. Raheman and Phadatare [10] 2004 Karanja biodiesel It reported low BTHE and higher BSFC obtained by biodiesel blends as correlated to convention diesel. In addition, the biodiesel blends produced less CO, NOx, and smoke emissions as correlated to convention diesel. Ramadhas et al. [11] 2005 Methyl esters of rubber seed oil It reported that higher BSFC and NOx emissions obtained by biodiesel blends as correlated to convention diesel. 14 S. Puhan et al. [12] 2005 Mahua oil methyl ester The results reported that biodiesel fuel has a low CV value, increasing the engine's BSFC value. Labeckas and Slavinskas [13] 2005 Rapeseed methyl ester and blends with diesel The NOx emissions because of the complete combustion of biodiesel. Yoshimoto [14] 2006 Rapeseed oil It reported that slight performance values enhanced but higher CO and NOx emissions because of the complete combustion of fuel. Pereira et al. [15] 2007 Soybean biodiesel The biodiesel blends produced less CO, HC, and sulfur dioxide (SOx) but higher NOx emissions correlated to convention diesel. Roskilly et al. [16] 2008 Biodiesel from recycled cooking oil It reported that higher BSFC and lower CO and NOx emissions obtained by biodiesel blends correlated to convention diesel. Altun et al. [17] 2008 Sesame oil blended with diesel The biodiesel blends produced less CO and NOx emissions as correlated to convention diesel. Correa and Arbilla [18] 2008 Commercial biodiesel It reported that low speeds produced higher total carbonyls as compare to higher speeds. 2.7 Effects of engine performance and emissions with different antioxidant A few research work did by blending antioxidant additives with diesel-biodiesel blends. Therefore, exploring the fullest potential is a new concept for researchers. Diesel fuel consists of unstable species, and it produced free radicals which combine with O2 to create further free radicals in a chain reaction and react with olefinic compounds to form gums. These can also polymerise to form 15 nitrogen, sulfur compounds, and organic acids to form sediments. Antioxidants inhibit chain branching reactions free radicals to form stable hindered radicals, which do not propagate further. It leads to fuel darkening and the production of gums and sediments, consequently reducing the fuel instability of biodiesel through the application of antioxidants. Many research studies argue that biodiesel used in diesel engines resulted in increased NOx emissions because of the oxygen content in biodiesel. Therefore, the vital feature of antioxidants is reduced NOx emission by absorbing excess oxygen while using biodiesel in fuel blends (Varatharajan et al., 16; Palash et al., 18). In this work, the literature studies the impacts on engine performance and emissions of various antioxidant additives with diesel-biodiesel blends. Ileri et al. [19] studied the effects of a turbocharged direct injection (TDI) diesel engine using biodiesel with antioxidants. The results reported that low BSFC obtained using Tertbutyl hydroquinone (TBHQ) antioxidant with biodiesel, among other fuel blends. The lower NOx emissions obtained by using 2-Ethylhexyl nitrate (EHN) antioxidants with biodiesel among all different fuel blends, but CO emissions were increases with all fuel blends. Varatharajan et al. [20] examined the use of various antioxidant additives blended with jatropha biodiesel as fuel on a CI engine. The results reported that low BSFC obtained using ethylenediamine and p-phenylenediamine but slightly increases with L-ascorbic acid, BHT and a-tocopherol as correlated to conventional biodiesel. The lower NOx emissions obtained by using all antioxidant additives, but p-phenylenediamine gave optimum reduction related to other fuel blends. The emission of CO and HC emissions increased with all antioxidant fuel blends. Palash et al. [22] conducted experiments on CI engine with the influence of performance and emission parameters by adding N, N'-diphenyl- 1,4-phenylenediamine (DPPD) antioxidant in jatropha biodiesel. The obtained results showed that this additive gave the same power and BSFC with and without adding the additive. The obtained results revealed that the reduction of NOx emissions increases with increased blends of biodiesel. However, it slightly increases the emissions of HC and CO. Still. It should be low compared to conventional diesel. Rashed et al. [23] investigated the effects on a diesel engine using Calophyllum biodiesel with antioxidants additives NPPD, EHN, and DPPD. The results showed high BSFC and low brake power (BP) and BTHE obtained using biodiesel without additives. The BP and BTHE of biodiesel with antioxidants were increased and reduced BSFC as compared to conventional biodiesel. These all antioxidants reduced NOx emissions but increased CO and HC emissions as compared to traditional biodiesel. 16 Karthikeyan et al. [24] investigated the effects of performance and emission characteristics on a diesel engine by using Pistacia khinjuk methyl ester (PB) with Geraniol (GE) and Pyrogallol (PY) antioxidants. The results reported that PB20 + PY blend noticed better performance characteristics than PB20 + GE. In addition, the lower CO, HC, and smoke opacity and NOx emissions of PB20 + PY blend compared to PB20 + GE blend. Katam et al. [25] studied the effects of the CI engine's performance and emissions using algal biomass as an antioxidant additive in coconut and karanja methyl esters. The results revealed that biodiesel blend with antioxidant showed high BTHE and low NOx emissions than biodiesel blends. Cristina Dueso et al. [26] investigated the effects of a diesel engine's performance and emissions using sunflower biodiesel with a renewable antioxidant additive from bio-oil. The results reported that a slight difference in performance parameters found with and without antioxidants of biodiesel. The antioxidant additive combined with the sunflower biodiesel reduced NOx emissions and smoke opacity and increased CO and HC emissions of the diesel engine compared to diesel.

2.1 Conclusions from the literature review

The conclusions of several studies in the literature reported that biodiesel as fuel in engine shows lower unburned hydrocarbon, carbon monoxide, smoke, and higher NOx compared to diesel due to its higher oxygen content, low aromatic compounds and lower compressibility. Biodiesel on diesel engines increases BSFC and lower BP because of lower CV, high viscosity, and density. The present review highlights the use of various antioxidants and nanoparticles blended with different biodiesels and an overview of biodiesel research progress and their effects on the performance and emissions of a diesel engine. This review study found that nanoparticle consists of a high CV, thermal conductivity, and surface to-volume ratio, enhancing diesel engine performance, combustion, and emissions. But a slight increase in CO2 emission was observed with nanoparticles added biodiesel compared to neat biodiesel and biodiesel-diesel blends. The antioxidants blended with biodiesel found to be more effective in suppressing the NOx emission by disrupting the chain propagating reactions, trapping free radicals, and decomposing peroxides. Adding antioxidants with biodiesel would improve engine performance slightly while decreasing NOx emissions but a slight increase in other emissions.

- The primary threat in the exploration of petroleum fuels is that it would decrease the petroleum reserves.
- In this context, renewable fuels would be a suitable alternative. Previous researchers found that the engines fuelled with biodiesel required high BSFC and emit lesser carbon monoxide (CO), lesser unburned hydrocarbon (UBHC), and particulate matter (PM) as compared to a diesel with an increase in oxides of nitrogen (NOx) emission.
- All the previous studies show that nano additives for all diesel and biodiesel fuel used in diesel engine enhanced performance appreciably.
- Some of the studies showed that increasing the concentration of the nanoparticles and antioxidant additives do not increase the performance proportionately or linearly. In some cases, it is unresponsive beyond a certain concentration level. • Previous studies found that nanoparticles' higher CV, thermal conductivity, and surfaceto-volume ratio properties enhanced engine performance, combustion, and emissions. But a slight increase in CO2 emission was observed with nanoparticles added biodiesel compared to neat biodiesel and biodiesel-diesel blends.
- The antioxidants blended with biodiesel found to be more effective in suppressing the NOx emission by disrupting the chain propagating reactions, trapping free radicals, and decomposing peroxides. Adding antioxidants with biodiesel would improve engine performance slightly while decreasing NOx emissions but a slight increase in other emissions.

REFERENCES

[1] technical sustainability of cashew nut shell liquid as a renewable fuel in compression ignition engine (https://www.researchgate.net/publication/283814423_technical_sustainability_of_cahew_nut_shell_liquid_as_a_renewable_fuel_in_compression_ignition_engine)

[2] rice bran oil-fueled ic engine performance and emission characteristics improved by nanoadditives. (volume 2023, article id 7341542)
[3] combustion, performance and emission characteristics of a di diesel engine fueled with mustard oil biodiesel fuel blends at different engine loads(doi:10.1016/j.fuel.2017.09.005)
[4] comparative evaluation of performance and emission characteristics of jatropha, karanja and polanga based biodiesel as fuel in a tractor engine (doi:10.1016/j.fuel.2009.02.015)
[5] effect of waste cooking-oil biodiesel on performance and exhaust emissions of a diesel engine (doi:10.1016/j.ejpe.2018.02.008)
[6] an experimental evaluation of engine performance and emisssion characteristics of ci engine operated with roselle and karanja biodiesel. (doi:10.1016/j.fuel.2019.115652)
[7] experimental investigation on performance, combustion and emission analysis of a direct injection diesel engine fuelled with rapeseed oil biodiesel. (doi:10.1016/j.fuel.2019.02.106)
[8] effects of biodiesel obtained from canola, sefflower oils and waste oils on the engine performance and exhaust. (doi:10.1016/j.fuel.2020.117026)
[9] diesel engine emissions and performance from blends of karanja methyl ester and diesel(volume 27, issue 4, october 2004)
[10] performance and emission evaluation of a diesel engine fueled with methyl esters of rubber seed oil (doi: 10.1016/j.renene.2005.01.009)
[11] performance and emission study of mahua oil (madhuca indica oil) ethyl ester in a 4-stroke natural aspirated direct injection diesel engine(volume 30, issue 8, july 2005, pages 1269-1278)
[12] the effect of rapeseed oil methyl ester on direct injection diesel engine performance and exhaust emissions(doi:10.1016/j.enconman.2005.09.003)
[13] performance of di diesel engines fueled by water emulsions with equal proportions of gas oil rapeseed oil blends and the characteristics of the combustion of single droplets(doi:10.4271/2006-01-3364)
[14] combustion of biodiesel in a large-scale laboratoryfurnace(https://doi.org/10.1016/j.ener gy.2014.07.077)
[15] the performance and the gaseous emissions of two small marine craft diesel engines fuelled with biodiesel (a.p. roskilly et al. / applied thermal engineering 28 (2008) 872–880)
[16] the comparison of engine performance and exhaust emission characteristics of sesame oil– diesel fuel mixture with diesel fuel in a direct injection diesel engine (doi: 10.1016/j.renene.2007.11.008)
[17] carbonyl emissions in diesel and biodiesel exhaust(https://doi.org/10.1016/j.atmosenv. 2007.09.073)
[18] screening of antioxidant additives for biodiesel fuels (https://doi.org/10.1016/j.rser.2017. 07.020)
[19] effects of antioxidant additives on engine performance and exhaust emissions of a diesel engine fueled with canola oil methyl ester–diesel blend (doi:10.1016/j.enconman.2013.07.037)
[20] impacts of n, n'-diphenyl-1, 4-phenylenediamine (dppd) antioxidant additive in jatropha biodiesel blends to reduce nox emission of a multi cylinder vehicle type diesel engine (doi:10.4028/www.scientific.net/amr.774-776.784)
[21] performance and emission characteristics of a diesel engine fueled with palm, jatropha, and moringa oil methyl ester(https://doi.org/10.1016/j.indcrop.2015.10.046)
[22] comparative analysis on the influence of antioxidants role with pistacia khinjuk oil biodiesel to reduce emission in diesel engine (published: 09 december 2019)
[23] the performance and emissions investigations of compression ignition (ci) engine using algal biomass as an antioxidant additive in coconut and karanja methyl esters(doi:10.1007/s40010-019-00623-6)
[24] performance and emissions of a diesel engine using sunflower biodiesel with a renewable antioxidant additive from bio-oil(doi:10.1016/j.fuel.2018.07.013)
[25] non-edible oils as the potential source for the production of biodiesel in india: a review (https://www.researchgate.net/publication/282394409_non edible_oils_as_the_potential_source_for_the_production_of_ biodiesel_in_india_a_review)
[26] overview of feedstocks for sustainable biodiesel production and implementation of the biodiesel (acs omega 2021, 6, 29, 19099–19114)
[27] recovery and utilization of crude glycerol, a biodiesel byproduct (doi: 10.1039/d2ra05090k)
[28] glycerolysis treatment to enhance biodiesel production from low-quality feedstocks
(https://doi.org/10.1016/j.fuel.2020.118970)