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BIODIESEL AS AN ALTRANATIVE FUEL – A REVIE

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Abstract: Biodiesel is a renewable, non-toxic, and biodegradable fuel produced from vegetable oils, animal fats, and waste cooking oils through transesterification, esterification, or hydro-processing. Optimal production parameters include temperature, raw material ratio, mixing speed, time, and catalyst type, with the goal of producing high-quality biodiesel. Biodiesel is a promising alternative to diesel fuel, offering similar properties and performance, with benefits including reduced emissions, improved thermal efficiency, and renewable energy source. Biodiesel production involves transesterification of vegetable oils, animal fats, or waste cooking oils with an alcohol, and its performance is influenced by factors like methanol to oil ratio, catalyst concentration, mixing speed, and reaction time. Research has focused on optimizing biodiesel production, examining its effects on engine performance, emissions, and sustainability, and addressing challenges like poor atomization and combustion efficiency to promote its use as a viable alternative fuel.

Key words: bio fuel, vegetable oil, transesterification, Esterification, hydro processing, Biodiesel.

1. INTRODUTION:

The world is facing an energy crisis due to the depletion of fossil fuels, environmental pollution, and increasing energy demand, leading to a search for alternative fuels like biodiesel.

Biodiesel, produced from animal fats or vegetable oils, is a renewable and cleaner fuel that can reduce carbon emissions and dependence on fossil fuels. Biodiesel can be produced from various feedstocks, including non-edible oils, waste cooking oil, and animal fats, and its performance characteristics, such as brake thermal efficiency and emissions, vary depending on the feedstock and engine configuration. Research has shown that biodiesel and its blends can reduce CO, HC, and smoke emissions, but may increase NOx emissions, and optimal engine operating configurations can improve efficiency and reduce emissions.

2. LITERATURE REVIEW:

1. Ahilan et al., Rising industrialization and motorization have increased the use of petroleum products, highlighting the need for alternative fuels like biodiesel, a renewable liquid fuel derived from biological sources through methyl esterification. This study examines the challenges of producing biodiesel from neem oil and assesses its fuel properties using a single-cylinder diesel engine. Tests with various blends showed that biodiesel outperformed diesel in brake thermal efficiency, with reduced specific fuel consumption and lower CO and smoke emissions but higher NOx emissions. Despite some challenges, neem oil-derived biodiesel shows promise as a renewable, eco-friendly diesel substitute.
2. Mohamed Khalaf et al., The increasing scarcity of fossil fuels and environmental concerns have intensified the search for sustainable alternatives like biodiesel. This study examines the performance, emissions, and sustainability of biodiesel from Jatropha and Castor seeds in diesel engines. Biodiesel production involved transesterification, with a focus on blends (B20, B40, B60) tested under varying engine loads. Jatropha biodiesel demonstrated superior performance and lower emissions compared to Castor biodiesel. Both biodiesel types showed comparable properties to conventional diesel, with B20 consistently performing best across all loads. Key findings include lower brake thermal efficiency (BTE), carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), and smoke emissions compared to diesel, but higher exhaust gas temperature (EGT) and nitrogen oxide (NOx) emissions. The increase in NOx emissions was linked to higher EGT and biodiesel's properties like viscosity and cetane number.
3. Naresh et al., Urbanization and population growth have led to increased fuel demand, causing a surge in fuel prices and heightened environmental concerns. Diesel engines emit harmful gases like sulfur oxides, nitrogen oxides, and carbon monoxide, contributing to issues such as acid rain, global warming, and health problems. The depletion of petroleum-based fuels has sparked a search for alternatives, with biodiesel emerging as a promising solution. Algal biofuel, derived from algae, is a notable alternative due to its minimal impact on freshwater resources and potential to be converted into biodiesel, bioethanol, or butanol. Unlike traditional biodiesel sources like soybeans and sunflowers, algae offer higher oil yields and faster growth rates, making it a superior option. This study examines the performance of a diesel engine using algae oil blends, utilizing Engine Soft, a software for engine performance monitoring.
4. Keunsang Lee And Haengmuk Cho et al., Addressing global environmental challenges, particularly those caused by automobile exhaust gases, is critical due to their contribution to

pollution and resource depletion. Idling engines, which emit significant fine dust and toxic gases, exacerbate these issues, making alternative fuels like biodiesel increasingly important. Biodiesel, derived from vegetable and animal sources or waste, is an eco-friendly alternative with properties similar to diesel. This study focuses on the emissions characteristics of biodiesel blended fuel in a Common Rail Direct-Injection (CRDI) diesel engine under idling conditions. Four types of biodiesels were tested: New Soybean Oil, New Lard Oil, Waste Soybean Fried Oil, and Waste Barbecue Lard Oil, comparing their emissions to pure diesel. Results showed that all B20 biodiesels reduced particulate matter, carbon monoxide (CO), and hydrocarbons (HC) compared to pure diesel, although nitrogen oxide (NOx) emissions increased. Specifically, New Soybean Oil showed the highest PM reduction (20.3%), while Waste Soybean Fried Oil led in CO (36.6%) and HC (19.3%) reductions.

5. Mozammil Hasnain Gaurav Kumar et al., This study investigates the performance and emission characteristics of a CRDI engine using various biodiesel blends of soy methyl ester (SME) and methyl oleate (MO) with diesel. The blends tested include SME100, SME50-M50, and different proportions of these blends with diesel (E25, E50, E75). The results show that while biodiesel blends, especially E25, offer reduced brake-specific fuel consumption (BSFC) compared to SME100, their BSFC is higher than diesel due to viscosity and heating value differences. BTE is highest for E25 and lowest for SME100. NOx emissions increase with higher blend proportions, with SME50-M50 showing the highest NOx emissions due to the unsaturation of MO.
6. Hailu Abebe Debella et al., This study investigated the performance and emissions of cottonseed oil methyl ester (CSOME) in a diesel engine. CSOME was blended with diesel fuel at various ratios: 5% (B5), 20% (B20), 50% (B50), 75% (B75), and 100% (B100). These blends, along with pure diesel (D2), were tested in a single-cylinder, direct-injection, air-cooled diesel engine to assess their impact on engine performance and exhaust emissions. The study found that blends with lower CSOME content (B5) slightly increased engine torque at medium and higher speeds compared to diesel fuel. However, there were no significant performance differences between B5, B20, and diesel fuel. Increasing the CSOME content generally reduced exhaust emissions. Specifically, CO emissions decreased with higher biodiesel content due to the oxygen in CSOME aiding combustion. Contrary to some reports, NOx emissions were lower for all blends except B5. The study also observed reduced SO2 emissions with biodiesel use, with B100 showing no SO2 emissions.

7. Fakher Hamdi et al., This research investigates the impact of biodiesel blends on Diesel engine performance and emissions using a single-cylinder, four-stroke, air-cooled engine under varying loads and speeds. Biodiesel was produced from sunflower oil via microwave-assisted transesterification. Three blends (B5, B10, B20) were tested against pure diesel (B0). Key findings include: at full load, specific fuel consumption (SFC) increased by 32% at 2400 rpm for biodiesel blends, while no significant power output change was observed. Brake thermal efficiency (BTE) improved at half load but decreased at full load for medium to high speeds. CO emissions dropped, especially with B10, showing a 40% reduction. CO2 and NOx emissions significantly decreased due to lower carbon content and combustion temperatures in biodiesel blends. This study highlights biodiesel's potential but suggests careful consideration of long-term storage effects on fuel properties.
8. Natalia K et al., The production of biodiesel fuel, a key alternative to conventional diesel, can significantly reduce harmful emissions. The main methods for biodiesel production include transesterification of vegetable oils, esterification of fatty acids from vegetable oils, and hydro processing using catalysts. These processes utilize various food and non-food oils, such as rapeseed, soybean, and palm oil, with different alcohols. Research indicates that transesterification, especially using red oil, is the most effective method, yielding fuel that meets many EN 590:2009 diesel standards. However, biodiesel fuels often need blending with hydrotreated diesel fuel to optimize their viscosity and lubricating properties, ensuring engine compatibility and longevity. The environmental benefits include lower sulfur levels, reduced carbon monoxide, and decreased exhaust smoke. While biodiesel production offers a sustainable fuel alternative, using non-food raw materials like red oil is crucial to avoid competition with food resources. This approach could improve fuel quality, expand resource options, and ensure environmental and economic sustainability.
9. Aman Singh Rajpoot et al., This study evaluates the combustion performance of a direct injection, one-cylinder CI engine using different biodiesels blended at 20% with diesel. Biodiesels from palm oil (P20), Jatropha oil (J20), and microalgae oil (M20) were tested under variable loads of 25% to 100%. Key performance indicators analyzed include heat release rate (HRR), cylinder pressure, ignition delay, exhaust gas temperature, brake thermal efficiency (BTE), brake-specific fuel consumption (BSFC), and NOx emissions. Results showed that M20 outperforms P20 and J20 across all parameters. At 100% load, the HRR ranged from 31.52 to 34.80 J/deg, cylinder pressure from 70.11 to 73.11 bar, ignition delay from 12.71 to 13.94 degrees, exhaust gas

temperature from 551.97 to 568.13 K, BTE from 31.86% to 32.67%, and BSFC from 259.31 to 289.35 g/kWh. NOx emissions varied from 425.5 to 876.65 ppm.

10. Abhirath Mandal et al., The study explores the feasibility of using waste fry oils as biodiesel in diesel engines, assessing the impacts on engine performance and emissions. Transesterification of used fry oils—first fry, second fry, third fry, and restaurant fry—produced biodiesel, which was then tested in a diesel agricultural engine with indirect injection. Biodiesel blends of 40% (B40) and 80% (B80) were evaluated at engine speeds from 1200 to 1800 rpm under 50% and 100% loads. The study concludes that waste fry oil biodiesel is a viable alternative to fossil diesel. The performance and emission characteristics varied with the fry time of the oil, with the first fry oil biodiesel performing best among the tested waste oils. This suggests that waste fry oils can be a sustainable and cost-effective substitute for fossil fuels in agricultural engines and transportation.
11. Arunkumar M et al., This study explores the use of biodiesel derived from milk wastewater using lipolytic microorganisms (LMD) as an alternative fuel for internal combustion (IC) engines. The process involves transesterification to convert milk wastewater into LMD and then evaluating its suitability in IC engines. Various biodiesel-diesel blends (B10, B20, B30, B40, B50, and B80) were tested in a single-cylinder direct-injection diesel engine across different loads (0, 25, 50, 75, and 100%). Key findings indicate that the addition of biodiesel reduces brake thermal efficiency (BTE) and brake specific energy consumption (BSEC). For blends with 10%, 20%, 30%, and 50% biodiesel, BTE decreased by 0.59%, 0.68%, 1.30%, and 2.98%, respectively. BSEC reduced by 0.1%, 0.3%, 0.44%, and 0.77% for similar blends.
12. Muhammad Idris et al., Diesel engines are commonly used in various sectors due to their efficiency, but the limited availability of diesel fuel has led to the exploration of biodiesel, a renewable and eco-friendly alternative. However, biodiesel's disadvantages, such as high viscosity and poor volatility, can hinder engine performance. Research has shown that additives like ED, made from natural components including citronella oil and various esters, can enhance biodiesel's performance by improving its properties. The results demonstrate that biodiesel mixed with ED can significantly boost engine power, torque, and efficiency. Specifically, engine power increased by up to 38.8%, torque improved by up to 2.7%, and SFC decreased by up to 6%. The best performance was achieved with a 0.04 gr ED mixture, showcasing substantial improvements in power, torque, and fuel consumption.
13. Yazan S. M. Altarazi et al., The study reviews alternative fuels, emphasizing biodiesel and its blends, and examines their performance and emissions in various engines over the past 30 years.

The rise in biodiesel use is driven by the need for sustainable, eco-friendly fuels as fossil fuels deplete. Biodiesel, derived from non-edible and edible oils, is noted for reducing pollutants like CO, CO2, NOx, and particulate matter, while also enhancing gas turbine performance. Liquid biofuels are preferred over solid biomass due to their better combustion properties and energy density. Biodiesel shares similar combustion characteristics with Petro diesel, making it suitable for gas turbines, particularly in small-scale micro gas turbines (MGTs). Technologies like high-temperature air combustion and catalytic combustion have improved emissions control and performance. Blending biodiesel with jet fuel has shown potential, but challenges remain, including high costs and the need for engine modifications.

14. Qixin Ma et al., Biodiesel is a promising alternative fuel for diesel engines, but its high viscosity and poor low-temperature flow properties limit its use. To address these issues, researchers are exploring alcohol additives in diesel-biodiesel (DB) blends. This study examined the effects of lower and higher alcohol contents on combustion and emissions in a modified single-cylinder diesel engine at varying speeds. The study found that the addition of n-pentanol improved combustion stability and reduced emissions of THC and CO compared to other blends. It also noted that lower alcohols, like n-pentanol, can enhance indicated thermal efficiency (ITE) and lower NOx and soot emissions. The findings suggest that using diesel/biodiesel/alcohol ternary fuels can be an effective strategy for improving diesel engine performance and reducing emissions. Future research should focus on unregulated emissions and performance under different fuel injection timings.
15. Veerbhadra Telganea et al., This investigation focuses on the production, characterization, and application of milk scum biodiesel as an alternative fuel for compression ignition (CI) engines. The study involved three stages: evaluating the suitability of milk scum oil as a feedstock, producing biodiesel, and analysing engine performance and emissions when using biodiesel blends. Milk scum biodiesel met ASTM D6751 standards, with a yield of 95% through a three-stage transesterification process. Although the fuel had lower low-temperature properties due to high saturated fatty acid content, it showed satisfactory characteristics such as a calorific value of 37,560 kJ/kg and low sulfur content. Engine tests revealed that using a B60 blend of biodiesel decreased brake thermal efficiency by 18.2% and increased brake specific energy consumption by the same percentage compared to diesel. However, emission characteristics improved significantly, with carbon monoxide (CO) emissions reduced by 50% and unburnt hydrocarbons (UBHC) by 6.8%. Nitrogen oxide (NOx) emissions increased by 33.4% at 2.7 kW load. Overall,

the study concludes that milk scum biodiesel is a viable alternative fuel with favourable performance and emission characteristics, despite some challenges in low-temperature conditions.

16. Ali Khan Jani et.al., This study explores the use of waste fish oil (WFO) biodiesel in water/diesel emulsion fuels to improve engine performance and reduce emissions. Various emulsion fuel formulations were created using ultrasound irradiation, with water, WFO biodiesel, and surfactant contents ranging between 3-7%, 3-7%, and 1-2%, respectively. A single-cylinder diesel engine's performance and exhaust emissions were analysed at 1800 rpm under full load. The study employed response surface methodology (RSM) for optimization, identifying the best formulation as 6.13% water, 3% WFO biodiesel, and 1% surfactant. Compared to neat diesel, this optimal emulsion showed a 6.33% decrease in engine torque, a 7.86% reduction in brake power, and a 9.52% increase in brake specific fuel consumption (BSFC). However, significant emission reductions were achieved, with a 42.86% drop in CO, 34.02% in unburnt hydrocarbons (UHC), and 25.53% in nitrogen oxides (NOx). The findings highlight that water/WFO biodiesel/diesel emulsions can effectively reduce harmful emissions, albeit with some trade-offs in engine performance.
17. P. Vignesh et.al., Ester molecules from animal fats and organic plant materials are being used in modern engine technologies. Two methods for converting esters into petroleum products are transesterification and hydro processing of ester bonds for biodiesel production. The European Commission has introduced a biofuel production plan, with biodiesel being used for 10% of conventional fuels in Europe by 2020. First-generation biodiesel, a mixture of methyl esters from fatty acids (FAME), is produced using low-value raw materials. Enzymes as biocatalysts can reduce production costs. Biodiesel and green diesel are complementary and can replace a few percent of the oil market.
18. Ezgi Suhal AKTAŞ et.al., Biodiesel is an alternative, non-toxic, biodegradable, and renewable fuel obtained from renewable energy sources like vegetable oils from oilseed crops like rapeseed, sunflower, soybean, safflower, animal fats, and short-chain alcoholic waste. It can be used as a fuel by mixing it with pure or any oil-based diesel. As the world's energy needs increase, interest in energy resources has started to increase. 80% of the energy sources used supply fossil fuels, with 70% being coal, 20% petroleum, and 10% natural gas. As fossil fuels' utilization rates decrease, the amount of reservoirs will decrease substantially in 100 years, and environmental pollution is estimated to increase by 50%. Transesterification is the most common method for producing biodiesel, which involves the conversion of one ester to another by exchange of

alkoxide groups. Rapeseed, sunflower, soy, and used frying oils, methanol as alcohol, and alkali catalysts (sodium or potassium hydroxide) are preferred for biodiesel production. Animal oils can also be used in biodiesel production.

19. Rickwinder Singh et.al., This study investigates biodiesel production and the impact of butanol (Bu)-biodiesel (B)-diesel fuels on diesel engines. Biodiesel is prepared from eucalyptus oil and tested with varying engine loads at 1500 rpm. Energy is crucial for development and economic growth, and non-renewable fuels like coal, natural gas, and petroleum are used in industries and transportation. Petroleum fuel consumption increases by 1.1% annually. The study examines engine performance and emission parameters for different fuel samples (B100, B20, B20-5Bu, B20-10Bu, B20-15Bu, and diesel) under test conditions. The biodiesel produced from eucalyptus oil and its blend (B20) has greater viscosity and density than diesel. The viscosity decreases with the addition of butanol, while brake power is nearly similar. The average increase in BSFC is 30%, 6%, 5%, 4%, and 5% for all fuel samples.
20. Medhat Elkelawya et.al., The study investigates the production of methyl ester from sunflower and soybean oil mixture using a catalyzed transesterification procedure. It examines the impact of reaction parameters on biodiesel yield and uses Box-Behnken design for process optimization. Biodiesel, a sustainable, renewable, eco-friendly, and energy-efficient fuel, is promising due to its biodegradability, non-toxic, and oxygenation properties. The biodiesel production process involved a small-scale catalyzed transesterification reaction using sunflower/soybean oil and methanol. A magnetic stirrer was used, with a working plate of stainless steel and brushless DC electromotor. Reaction parameters were optimized using Box-Behnken design and Central Composite Design Method to maximize methyl ester yield and optimize engine performance and emissions.
21. Sedef Köse1 et.al., This study investigates the production of biodiesel from waste sunflower oil using a transesterification method. It examines its impact on engine performance and fuel consumption. The increasing demand for sustainable energy sources, coupled with the risk of exhaustion from fossil fuel reserves, prompts researchers to explore alternative fuels and renewable energy sources, with biomass energy being a significant method in this research.
22. Pankaj Shrivastava et.al., This study examines the effects of different blends of Roselle biodiesel on compression ignition engines, comparing them with diesel fuel. Diesel engines are used for industrial, transportation, and agriculture due to their high efficiency and lower emissions. Researchers aim to control NOx, CO2, and smoke emissions from engine exhausts, with minor

modifications in engine setups potentially reducing these emissions. The study uses transesterification processes to produce Roselle biodiesel from Roselle oil in Raipur, Chhattisgarh, India. The process involves breaking down Roselle oil molecules into methyl or ethyl ester, with glycerin as a by-product. The experiment was performed on a single cylinder compression ignition engine, comparing engine characteristics with standard diesel fuel, and using different blends of Roselle biodiesel blends.

23. Upendra Rajaka et.al., The study investigated the effects of spirulina microalgae biodiesel blends on a naturally aspirated diesel engine. Results showed that SMB1 (20% biodiesel and 80% diesel) produced lower emissions and cylinder pressures compared to diesel fuel. Karanja Jatropha biodiesel showed superior atomization and condensation behaviour. The study also found that biodiesel blends had a 11% lower heating value than diesel, and flash points of over 150°C.The experimental setup included a dynamometer, fuel tank, control valve, data acquisition system, exhaust gas analyzer, and sensors. Engine stability tests were conducted to minimize errors. Lubrication, cooling, and fuel systems were checked. Cylinder peak pressure increased with spirulina microalgae biodiesel addition, while brake thermal efficiency reduced up to 3.03% at 100% load.
24. Mandeep Singh et.al., The study examined the performance, emission, and combustion characteristics of a 4-cylinder turbocharged, intercooled, common rail direct injection engine using argemone biodiesel-diesel blends. The physicochemical properties of biodiesel-diesel blends were compared with ASTM D6751 and tested on a 1.9L engine at low, part, and high load conditions. Biodiesel blends performed better at part and high loads.
25. M.A. Asokan et.al., Juliflora biodiesel, produced using a 2-stage acid transesterification process, has been tested in a single-cylinder diesel engine. The results showed that B20 had similar performance and combustion characteristics to diesel, with comparable Brake Specific Fuel Consumption and Brake Thermal Efficiency. The emission characteristics were lower or equal to diesel, except for slightly higher NOx emissions for B100. B20 was identified as the most suitable blend, reducing diesel consumption by 20%, making it a promising substitute for diesel fuel. Biodiesel and its blends can reduce CO, HC, and smoke emissions, but may increase NOx emissions. Blends like B20 offer a balance between performance and emissions.
26. Piyushi Nautiyal et.al., The study investigates the potential of biodiesel from Spirulina platensis algae as an alternative fuel for conventional diesel. The results show that biodiesel-diesel blends have lower ignition delay periods and lower heat release rates than base diesel. The duration of

combustion for base diesel, B10, B20, and B100 algae biodiesel-diesel blends was found to be 37.5 CA, 38 CA, 38 CA, and 40 CA respectively. Biomass-derived fuels contribute 8-15% of the world's energy for transportation, with an expected increase to 33-50% by 2050. Biodiesel from Spirulina platensis algae met European and American standards and showed similar brake thermal efficiency to diesel. However, it increased NOx emissions due to advanced injection timing, oxygen content, and higher adiabatic flame temperature.

27. Medhat Elkelawya et.al., The study investigates the impact of diesel/biodiesel blends on engine combustion, performance, and exhaust gas emissions. The researchers prepared three blends: D70B30, D50B50, and D30B70, each with a different percentage of biodiesel. Biodiesel, produced from vegetable oils and animal fats, meets energy efficiency requirements with minimal engine modifications. It provides the same thermal energy as diesel fuel, is low in sulfur and minerals, and helps self-lubricate engine mechanical parts. The study found optimal reaction conditions for producing biodiesel from sunflower and soybean oil mixtures, with a maximum yield of 93.5%. Biodiesel blends reduced CO, HC, and CO2 emissions but increased NOx emissions. Engine performance decreased with increasing biodiesel percentage.
28. K. Vamsi Krishnaa et.al., A study aimed to address the limitations of ordinary diesel engines, including low efficiency and high exhaust emissions, by using a modified engine with thermal barrier coating and a renewable fuel blend (rubber seed-based biodiesel and diethyl ether). The engine was operated at various loads and start of injection (SOI) timings. The study found that advancing SOI timing improved performance and emissions, except for NOx. The SADE with the blend fuel showed better results than the ordinary diesel engine (ODE) with diesel, with an optimum configuration of 7% increase in BTE, 5.5% reduction in BSEC, and significant reductions in particulates, NOx, and exhaust gas temperature at 330 BTDC with higher load. The study also investigated the use of non-edible oil sources like rubber seed-based biodiesel as a sustainable alternative fuel.
29. A. Khalid et.al., Biodiesel, a fuel produced by chemically reacting lipids from palm, vegetable, and waste cooking oils with alcohol-producing fatty acid esters, is not efficient in cold weather due to its viscosity, which affects fuel flow rate and poor fuel atomization. The automotive industry, which contributes to air pollution, is increasingly using biodiesel as a fuel source. This experiment studied the effects of three types of preheated biodiesel fuel blends (CPO, JCO, and WCO) on engine performance and emissions under load conditions and engine speeds. Results

showed that the biodiesel preheated blend significantly influenced engine performance and emissions.

30. K. Sivaramakrishnan et.al., The study investigates the performance and emission of single cylinder four stroke variable compression multifuel engines when fueled with 20%, 25%, and 30% Karanja blended with diesel. The experiment was conducted at compression ratios of 15:1, 16:1, 17:1, and 18:1. The study reveals that the impact of compression ratio on fuel consumption, brake thermal efficiency, and exhaust gas emissions is significant. The study also highlights the potential of bio-diesel production from non-edible oils, particularly in developing countries like India. The brake thermal efficiency of the blends increases with increasing compression ratio, with the maximum brake thermal efficiency of 30.46% at full load at compression ratio 18. The study concludes that Karanja oil blends provide higher combustion pressure at high compression ratios.
31. A. Rajalingam et.al., Biodiesel, derived from vegetable oils and animal fat, is an alternative fuel that can meet future fuel demand and reduce pollution. Four methods are used to produce biodiesel: direct use and blending, transesterification process, pyrolysis, and micro emulsion. Biodiesel is a mono alkali ester with neutral carbon emissions, making it suitable for green combustion. However, it cannot be used in direct injection engines due to its unacceptable properties. To improve fuel quality and reduce fossil fuel consumption, the transesterification process is considered the best biodiesel production method. It also yields glycerol, which can be used for other applications.
32. C.S. Padmavati et.al., Biodiesel is an emerging alternative fuel for diesel engines, derived from vegetable oils or animal fats through transesterification with alcohols. The depletion of fossil fuels is causing energy crises and rising global crude petroleum prices, impacting countries like India. Biodiesel is a sustainable, eco-friendly alternative, and vegetable oil is a promising alternative due to its advantages. However, the higher viscosity of vegetable oil-based biodiesel has been addressed through preheating, blending, transesterification, and pyrolysis. There is no clear consensus on the use of biodiesel, and the concept may not be commercialized to the expected extent due to the differences in performance and emission parameters across different engines and biofuels.
33. Ajeet Kumara et.al., The increasing demand for energy due to industrialization and domestic needs is putting pressure on conventional energy sources, which are already producing hazardous emissions. To address this, researchers have found an alternative fuel, biodiesel, which can be produced from various feed stocks and has negligible environmental impact. This paper analyzes

the performance and emission of biodiesel, focusing on its potential as an alternative fuel source. The first use of peanut oil by Rudolf Diesel in 1893 led to the use of vegetable oils as a substitute for diesel oil. The first international conference on plant and vegetable oils as fuels in 1982 discussed the primary concerns of cost, engine performance, durability, and standardization of fuel production. Experimental works using vegetable oils as I.C. engine fuel substitutes showed comparable thermal efficiency and particulate emissions, making them potential diesel fuel substitutes.

34. Amir Khalid et.al., Biodiesel, a green and renewable energy, has gained popularity as an alternative fuel for diesel engines due to socioeconomic and environmental concerns. The production of greenhouse gases (GHGs) from fuel combustion contributes significantly to these emissions, causing a shift in the climate system. Biodiesel is classified as an alternative fuel and has been shown to reduce CO2 emissions in compression ignition (CI) diesel engines. However, challenges remain in its use, particularly in light of environmental concerns and rising crude oil prices. A study using three types of biodiesel derived from different CPO, JCO, and WCO was conducted to investigate engine performance and emissions characteristics for different loads and engine speeds.
35. Senthil Ramalingam et.al., The addition of 1,4-dioxane to Annona biodiesel (A20) enhances its cold flow and ignition temperature properties, with the optimal blend being A20-10 ml (99.0% A20 + 1.0% 1,4-dioxane). This blend significantly improves engine performance and emissions reduction, with a 6.48% increase in brake thermal efficiency, 29.7% reduction in hydrocarbon emissions, 20% reduction in carbon monoxide emissions, 16.87% reduction in oxides of nitrogen emissions, and 25.51% reduction in smoke emissions. The experiment also investigated the effect of pyrogallol on the performance and emission characteristics of waste cooking oil operated diesel engines. The addition of 1,4-dioxane with A20 blend showed a reduction in exhaust emissions and improved performance in a single-cylinder diesel engine.
36. Mohamad A et.al., This study explores the use of biodiesel in a single-cylinder direct-injection diesel engine, comparing its properties and compound structure with petrol diesel under full load conditions. Biodiesel, derived from vegetable oils, animal fats, and waste cooking oils, consists of mono-alkyl esters off fatty acids. The study also examines the effect of a multipurpose additive, 1,4-dioxane, on emission and performance with A20 blend. Results show a reduction in exhaust emissions and improved performance in a single-cylinder diesel engine when added to the A20

blend. The BSFC and BTE for A20-10ml 1,4-dioxane were improved by 6.87% compared to the A20 without additive, while HC, CO, NOx, and smoke emissions were reduced by 29.7%, 20%, 16.87%, and 25.51%, respectively.

37. Yogendra Prasad Upadhyay et.al., Biodiesel is a renewable alternative fuel for diesel engines, produced by chemically combining vegetable oils and animal fats with alcohol to form alkyl esters. This research focuses on the optimal conditions for soya diesel production using methanol alkaline transesterification reactions. Biodiesel has a 12% lower energy content than petroleum-based diesel fuel and is an oxygenated fuel with a higher molecular weight, viscosity, density, and flash point than diesel fuel. It produces less unburned hydrocarbons, carbon monoxide, and particulate matter than diesel-fueled engines. Biodiesel can be used as a replacement for diesel fuel and in blends, with vegetable oils from various oil crops, microalgae grown in ponds, photo biological reactors, and used cooking oils and fat residues from the meat processing industry. The research aims to obtain a high-quality biodiesel fuel with the specifications of ASTM D 6751 and EN 14214.
38. M. Rakib Uddin et.al., The study synthesized biodiesel from Waste Cook Oil (WCO) using a three-step method. The raw oil, containing 1.9wt% Free Fatty Acid (FFA), was collected from a local restaurant in Sylhet, Bangladesh. The transesterification method yielded lower yields than the three-step method. Vegetable oils have a comparable calorific value to diesel, making them suitable for compression ignition engines. However, diesel engines emit pollutants that can harm human health and the environment. The biodiesel was prepared using a three-step method, with the optimum molar ratio for saponification being 1:2 oil to NaOH and a reaction time of 2.0h at 100°C. The optimum molar ratio for esterification was 6:1, with a catalyst concentration of 5wt% of FFA and a reaction temperature of 60°C.
39. S. Jaichandar et.al., The study explores the use of biodiesel as a renewable alternative to diesel oil in internal combustion engines. Biodiesel, derived from vegetable sources, offers a promising alternative with similar properties to conventional diesel fuel. Its performance, fuel consumption, and thermal efficiency are compared with conventional diesel fuels. Biodiesel is an oxygenated fuel, reducing emissions of carbon monoxide and soot. It also maintains CO2 balance and is classified as a non-flammable liquid by the Occupational Safety and Health Administration. Experimental studies on biodiesel-fuelled diesel engines show acceptable performance characteristics like fuel consumption, thermal efficiency, and emissions reduction. However, some studies show no improvement in thermal efficiency and suggest exhaust. The main issues with

vegetable oil substitution are high viscosities and low volatilities. Transesterification reduces these issues, leading to bio-diesel. Biodiesel and blends have similar fuel properties and combustion characteristics, making them an acceptable alternative to conventional diesel engines.

40. Husey in Aydina et.al., The study investigated the performance and emissions of cottonseed oil methyl ester in a diesel engine. The blends were tested in a single cylinder, direct injection, air-cooled diesel engine at various engine speeds and full loaded. Results showed that increasing CSOME in the blends decreased torque, possibly due to higher viscosity and lower heating value. At lower engine speeds, B20's bsfc's were observed to be lower than other fuels, making cottonseed oil a promising biofuel alternative.

3. CONCLUSION:

Biodiesel Production and Characterization: Biodiesel can be produced from various plant raw materials, including non-food sources like red oil, and waste materials like used cooking oil and fat residues. The produced biodiesel can be blended with hydrotreated low-Sulphur diesel fuel to improve its quality.

Engine Performance: Biodiesel and its blends with diesel fuel have been tested in various engine experiments, showing improvements in engine performance, including increased power and torque, and reduced specific fuel consumption.

Emission Characteristics: The use of biodiesel and its blends has been found to reduce exhaust emissions, including particulate matter (PM), hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx), compared to standard diesel fuel.

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