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Performance and Emission Characteristics of C.I Engine Equipped with EGR and Chicken Waste Based Biodiesel Blended as a fuel

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Abstract:**As the world's fossil fuel stocks continue to dwindle at an alarming rate, people are exploring alternatives using oils derived from plants and animals. While most vegetable oils are safe for human consumption, there has been rising interest in experimenting with non-edible and waste fats as a replacement for petro diesel. As in the process of bringing forth clean and green energies into economical usage, manufacturing of Bio-diesel from chicken waste, which is a waste product all over the world generating, disposal problem, has tried. Main purpose of the present study is to analyse the performance and emissions characteristics of biodiesel obtained from chicken waste oil in an unmodified diesel engine and to compare the results with baseline values of diesel fuel. Experimental evaluations of key physicochemical features of transesterified chicken waste oil were determined to be within acceptable limits of applicable standards.In this study, we compare the braking thermal efficiency of biodiesel made from chicken waste at 20%, 40%, and 60% concentrations with that of mineral Diesel, among other performance indicators. Diesel fuel, which has fewer oxygen atoms than biodiesel fuels, produces more carbon monoxide. The increased oxygen content in biodiesel fuel molecules and the lower cetane number (CN) of biodiesel fuels cause biodiesel fuels to produce more NOX than diesel fuel. The drop in flame temperature and the increase in O2 in the fresh air charge cause CO to rise and NOX to fall as EGR is increased. The BTE of diesel was 1.7%-18% lower when blended with biodiesel made from chicken manure. Carbon monoxide, carbon dioxide, unburned hydrocarbon (UBHC), oxides of nitrogen, and smoke opacity were all measured as emission parameters for various test fuels. Chicken waste biodiesel fuel had lower levels of UBHC, CO, CO2, and smoke. When compared to Diesel, however, both pure chicken waste biodiesel and its combination produced more nitrogen oxide emissions.**

Keywords:Biodiesel, chicken waste based biodiesel, alternative fuel, diesel engine,performance, Emission characteristics, and blend.

I. INTRODUCTION

Bio-fuels, namely, vegetable oils and animal fat oil can be used as fuels for diesel engines. Vegetable oils and animal fat oil can be directly used in diesel engines as they have a high cetane number and calorific value, which are very similar to those of diesel. However, the brake thermal efficiency of vegetable oils and animal fat oil is inferior to that of diesel. This leads to problems of high smoke, HC and CO emissions. This is because of the high viscosity and low volatility of vegetable oils, which lead to difficulty in atomizing the fuel and mixing it with air. Further, gum formation and piston sticking under long-term use due to the presence of oxygen in their molecules and the reactivity of the unsaturated HC chains, present problems in the use of vegetable oils. These problems were overcome by chemically altering the vegetable oil and animal fat oil (transesterification) and blending it with diesel [1–4]. Transesterification of vegetable oils and animal fat oil resulted in better performance and reduced emissions. The cetane number is also improved. It has been reported that the methyl ester of vegetable oils offers lower smoke levels and higher thermal efficiencies than neat vegetable oils [5]. Further, it has been reported that the thermal efficiency of the engine increases with an increase in the methanol fraction in diesel due to an increased fraction in the premixed combustion phase with marked reductions in CO and HC emissions [6]. A marginal increase in NOxemission and a reduction in CO, HC and smoke, due to the presence of oxygen in neat bio-diesel and biodiesel– diesel blends were recorded and reported [7]. The behavior of the bio-diesel prepared from modified feed stocks

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was studied and it was reported that the engine performance and combustion process of all the blends were similar to those of diesel fuel with marginally higher fuel consumption, a shorter ignition delay, and a lower premixed burning rate [8]. The effects of cetane number and fuel injection pressures on a diesel engine emission and on its performance were reported. The results showed that NOx, and CO emissions reduced by about 15% and 5%, respectively.

The use of crops or waste as an efficient, cost-effective, locally-available and sustainable source of energy has increased, bringing opportunities for farmers and governments alike, while also benefiting the environment. In this context, research has been focused on bio-fuels as alternative fuels for internal combustion engines. Bio-fuels, namely, vegetable oils and animal fat oil can be used as fuels for diesel engines. Feather meal has a great potential as an alternative, non-food feedstock for the production of bio fuel as it consists of 12% fat content. Chicken feather meal (mixture of chicken waste), processed at high temperatures with steam in order to extract oil. This feather meal contains high percentage of protein and nitrogen. Also another advantage of extracting oil from feather meal is that it provides both high-grade animal feed with better nitrogen source for fertilizer applications. By the large amount of feather meal generated by the poultry industry every year, millions of gallons of biodiesel can be produced worldwide. In this paper it is analyzed about the performance test conducted on stationary single cylinder diesel engine by using chicken waste based biodiesel blends with diesel fuel with and without EGR for no load to full load condition at constant speed .Chicken waste based biodiesel is blended with petroleum diesel in proportion like 20%, 40% and 60%.These blends are termed as CWBD20, CWBD40 and CWBD60. Engine Performance and emissions using these blends and pure diesel have been evaluated and presented in following articles. The performance, emission and combustion studies were carried out on a medium capacity compression ignition engine which was fueled with chicken waste based methyl ester and its blends with diesel.

II. PRODUCTION OF CHICKEN WASTE BIODIESEL

The various steps involved in extracting biodiesel from chicken waste are as follows.

A. Step 1: Chicken waste collected from local chicken shop, is taken into a vessel and, boiled with sufficient quantity of water, by maintaining temperature above 100^0 centigrade. After evaporation of water, the left out stock is squeezed to extract oil, which is further heated to have moisture free oil.

*B Step 2: Mixing of alcohol and catalyst to the raw oil:*The catalyst is typically calcium oxide (lime) which isdissolved in the alcohol using a standard agitator or mixer. The alcohol/catalyst mixture is then charged into a closed reaction vessel and there oil or fat is added. The system from here on is totally closed to the atmospheric exposure, to prevent loss of alcohol. The reaction mixture is kept just above the boiling point of the alcohol (around 160 °F) to speed up the reaction. Recommended reaction time varies from 1 to 8 hours, and some systems recommend the reaction take place at room temperature. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters. Care is taken to monitor the amount of water and free fatty acids in the incoming oil or fat. If the free fatty acid level or water level is too high it may cause problems with soap formation and the separation of the glycerin by-product downstream.

*C Step 3:*During the Esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like concentrated H_2SO_4. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel, and crude glycerol. In most of the processes, methanol or ethanol is the alcohol used (methanol produces methyl esters, ethanol produces ethyl esters) and is base catalyzed by either potassium or sodium hydroxide. Potassium hydroxide has been found more suitable for the ethyl ester biodiesel production, but either base can be used for methyl ester production. The following proportions of chemical reactions are suitable for Esterification of chicken fat oil.

Reaction I : Esterification

1000ml chicken fat oil +2.5 ml concentrated H_2SO_4 +450ml Methanol [CH_4OH]

Reaction Temperature set = 60˚c,

Reaction Time = 1Hour [60Minutes]

*D Step 4:*Transesterification of natural glycerides with methanol to methyl esters is a technically important reaction that has been used extensively in the soap and detergent manufacturing industry worldwide for many years. Almost all biodiesel is produced in a similar chemical process using base catalyzed Transesterification, as it is the most economical process, requiring only low temperatures and pressures while producing a 98% conversion yield. The Transesterification process is

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the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerin molecule as its base is attached with three long chain fatty acids .The characteristics of the fat are determined by the nature of the fatty acids attached to the glycerin. The nature of the fatty acids can, in turn, affect the characteristics of the biodiesel. Jug dale et al. [4] found that following proportions of chemical reactions are suitable for Transesterification of chicken fat oil.

Reaction II : Transesterification

CaO [Base catalyst] + 100ml methanol + 1475[first reaction Proceed] 1575ml

Reaction Temperature=60˚c, Reaction Time = 1Hour [60Minutes]

Pure chicken fat biodiesel Quantity after Transterification from 1500gram chicken fat=990 ml.

*E.Step 5: Separation Process of Glycerin and Biodiesel:*Once the reaction is complete, two major products exist: glycerin and biodiesel. Each has a substantial amount of the excess methanol that was used in the reaction. The glycerin phase is much denser than biodiesel phase and the two can be gravity separated with glycerin simply drawn off the bottom of the settling vessel. In some cases, a centrifuge is used to separate the two materials faster. A successful reaction produces two liquid phases: ester and crude glycerol. The entire mixture then settles and glycerol is left on the bottom and methyl esters (Biodiesel) is left on top. Crude glycerol, the heavier liquid will collect at the bottom after several hours of settling. Phase separation can be observed within 10 min and can be complete within 2 h after stirring has stopped.

*F. Step 6: Alcohol Removal:*Once the glycerin and biodiesel phases separated, this excess alcohol in each phase is removed with a flash evaporation process or by distillation. In others systems, the alcohol is removed and the mixture neutralized before the glycerin and esters have been separated. Care must be taken to ensure no water accumulates in the recovered alcohol stream.

Table 1: Properties of Chicken Waste Biodiesel.

III. PROPERTY ANALYSIS

The physical-chemical properties of chicken waste oil methyl Easter compared with those of diesel fuel and given in Table 1. It can be observed that the oil have important properties comparable with those of diesel fuel, and are also within the limits prescribed by IS 1460-1974, except the cetane number of chicken waste oil. When chicken waste oil, which has high volatility and low viscosity, blended with methyl ester, it resulted in a fuel with reduced viscosity and increased volatility. The reduction in viscosity and increase in heating value would result in better engine performance. The volatility of the blend also increased, which led to fine atomization and better spray formation. Important properties of bio-fuels like lower heating value, flash point, and viscosity are comparable with those of diesel. The fatty acid composition of this methyl ester is similar to that of other types of methyl esters. One feature of this oil is the presence of oleic acid as the major constituent. This oleic acid enhances the performance of the diesel engines by reducing carbon deposits, and injector coking. The carbon atoms linked to ether oxygen are fully substituted and this fact, together with the chemical saturation (no carbon–carbon double bonds) endows cineole with stability and low chemical reactivity. These properties include resistance to oxidation, polymerization and thermal decomposition, in contrast to most other terpenoid compounds. Cineole's ether oxygen atom is moderately polar, making it either fully or partly miscible in a wide range of other liquids, from hydrocarbons to polar organics

Sl.No	Characteristics	Unit	Test Method	B100
1	Density	gm/cc	ASTMD1448	0.8859
2	Calorific value	Mj/kg	ASTM D6751	33.747
3	viscosity	Cst	ASTMD445	4.37
4	Flash point	˚c	ASTMD93	95˚c
5	Pour point	˚c	ASTMD2500	-3˚c
6	Cloud point	˚c	ASTMD2500	+8˚c
7	Carbon residue	%	ASTMD4530	0.32%
8	Cetane number	-	ASTMD613	58.4

IV. EXPERIMENTAL SETUP

The Performance test is conducted on a high speed, four stroke, vertical, air cooled diesel engine. The loading is by means of an electrical dynamometer. The fuel tank is connected to burette to measure the quantity of fuel consumed in unit time. An orifice meter with U-tube manometer is provided along with an air tank on the suction line for measuring air consumption. An AVL15 smoke meter is provided for measuring FSN of exhaust gases. The test rig is installed with AVL

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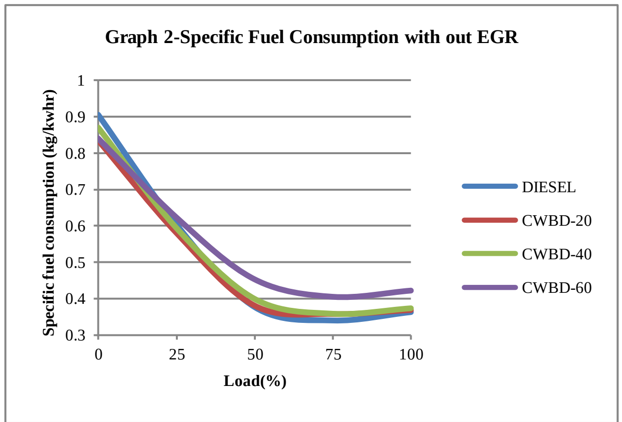
software for obtaining various data and results during operation. A five gas analyzer is used to obtain the exhaust gas composition.Computerized Single Cylinder Diesel Engine Test Rig specifications are given below.



Description	Value
Manufacturer	Kirlosker oil engines Ltd .,Pune
Engine Type	Single Cylinder, 4 Stroke, vertical air cooled, and Diesel engine.
Cylinder	Single
Stroke	110mm
Cubic capacity	661 cc (0.661 ltr.)
Bore	87.5 mm
Net Power	4.4kw @ 1500 rpm
Compression Ratio	17.5 :1

Table 2: Engine specifications

V. ENGINE PERFORMANCE ANALYSIS

A. Specific fuel consumption: An increase in biodiesel fuel consumption due to low heating value, high density and high viscosity of biodiesel, but this trend will be weakened as the proportion of biodiesel reduces in the blend. The variation of Specific fuel consumption with load for chicken waste biodiesel blends and diesel is shown in below fig. CWBD 60 and CWBD 60 with EGR have specific fuel consumption more than other blends. CWBD 40 has Specific fuel consumption nearly equal to diesel at all load conditions. Diesel with EGR has nearly less fuel consumption than other blends. CWBD 20, CWBD 40and CWBD 60 has 1.62%, 2.68% and 13.9% higher Specific fuel consumptionthan diesel at full load condition. CWBD 20, CWBD 40and CWBD 60 with EGR has 8.63%, 18%, and 28.6% higher Specific fuel consumptionthan diesel with EGR at full load conditions.

B. Brake Thermal Efficiency: The variation of brake Thermal Efficiency with load for chicken waste biodiesel blends and diesel is shown in below figs. CWBD 60 with EGR has lowest brake thermal efficiency than other blends at 0%, 25%&50% and full load conditions. This is due to the combined effect of higher viscosity, higher density and lower calorific value. Diesel has highest brake thermal efficiency at 50% load condition. CWBD 40 has higher brake thermal efficiency at 75% load condition than other blends. CWBD 20, CWBD 40and CWBD 60 has 1.74%, 5.96% and 8.72% less Brake Thermal Efficiencythan diesel at full load condition. CWBD 20, CWBD 40and CWBD 60 with EGR has 4.9%, 11.13%, and18.86% less Brake Thermal Efficiencythan diesel with EGR at full load condition

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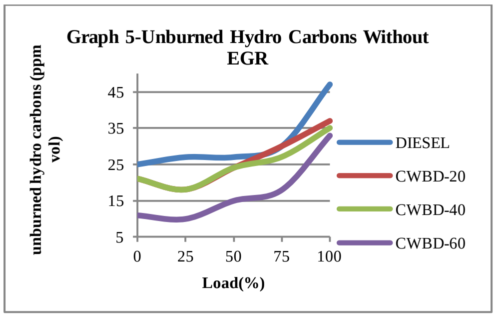
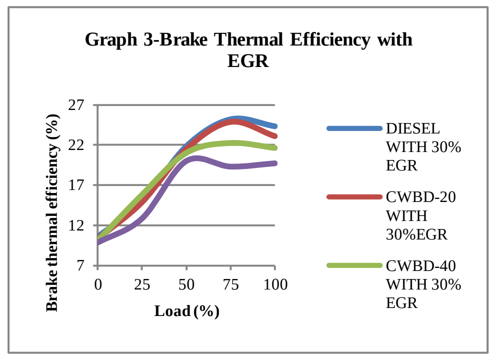
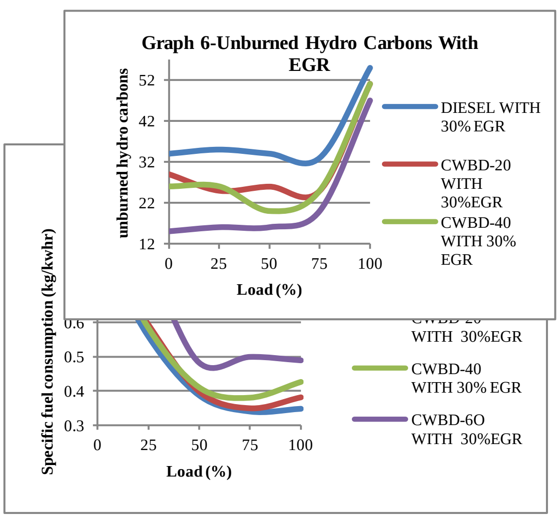
VI. EMISSION ANALYSIS:

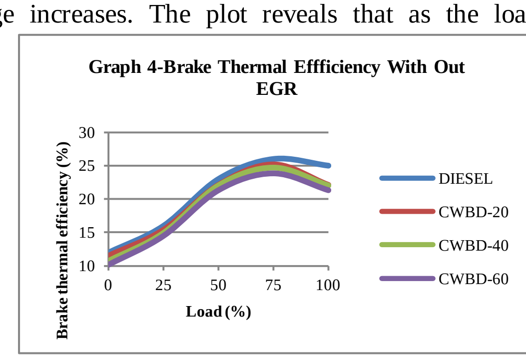
*A. Unburned Hydrocarbon (HC):*The variation of HC emission with load is shown in above graphs 5&6. HC emissions are reduced when biodiesel is fueled in place of diesel. This reduction is mainly contributed to the higher oxygen content of biodiesel. The plot reveals that as the load increases the HC emission increases. Diesel with EGR has more HC emissions than other blends at 0%, 25% &75% load conditions. CWBD 60 has less HC emissions at all load conditions when compared to other blends. The variation of CO emission with load is shown in above fig. Lower HC emissions may be due to efficient combustion of CWBD 60 by the presence of bounded oxygen. CWBD 20, CWBD 40and CWBD 60 has 21%, 25 % and 29.7% less Unburned Hydrocarbon than diesel at full load condition. CWBD 20, CWBD 40and CWBD 60 with EGR has 7.2%, 7.2%, and14.5% less Unburned Hydrocarbon than diesel with EGR at full load conditions.





*B. Oxides of nitrogen (NO_x):*The variation of NO_x emission with load is shown.Nox formation increases as load is increased, which is a result of higher combustion temperature due to higher engine load; i.e. No_x concentration varies linearly with load. As the load increases the overall fuel air ratio increases which results in an increase in the average gas temperature in the combustion chamber and No_x formation which is sensitive to temperature change increases. The plot reveals that as the load increases theNO_x emissions increases. CWBD 40 with EGR and CWBD 60 with EGR have more No_x emissions at all load conditions when compared to other blends. Diesel has less No_x emissions at 0%, 25%, 50% and 75% load conditions than other blends. CWBD 20, CWBD 40and CWBD 60 has 14.8%, 22 % and 27% higher Oxides of nitrogen than diesel at full load condition. CWBD 20, CWBD 40and CWBD 60 with EGR has 10.4%, 17.9%, and20.5% less Oxides of nitrogen than diesel with EGR at full load conditions.





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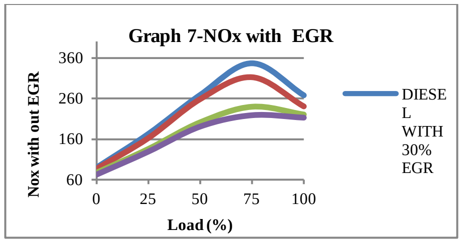
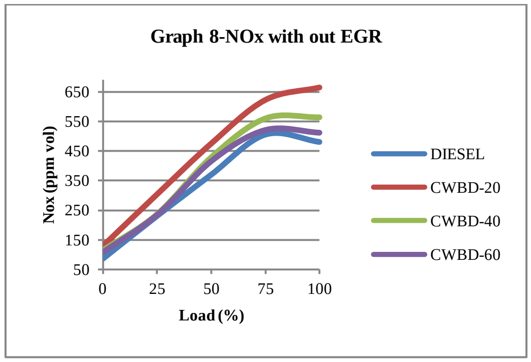
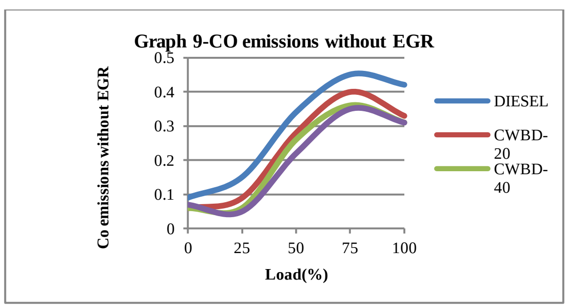
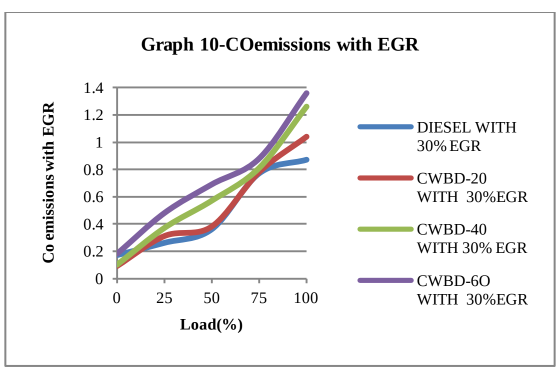




*C. CO Emissions:*The variation of CO emission with load is shown.Generally CO emissions reduces with biodiesel due to the higher oxygen content and the lower carbon to hydrogen ratio in biodiesel compared to diesel. Another reason for decrease in CO emissions in biodiesel is it has higher cetane number which results in the lower possibility of formation of rich fuel zone which reduces CO emissions. CWBD 40 with EGR has more CO emission at 75% and full load condition. By using EGR there may not be sufficient availability of oxygen for the complete combustion of fuel. CWBD 60 and diesel has same CO emissions at all load conditions. CWBD 20 and CWBD 40 have same CO emission at all load condition. CWBD 20, CWBD 40and CWBD 60 has 42%, 45.6 % and 45.6% less Co emissions than diesel at full load condition. CWBD 20, CWBD 40and CWBD 60 with EGR has 16.3%, 30.9%, and 36% higher Co emissions than diesel with EGR at full load conditions.





*D. Smoke Opacity:*Graphs 11&12shows the variation of the smoke opacity of Diesel and chicken methyl esters and its blends at different load. It can be seen that smoke is high mainly at high power outputs. High loads imply that more fuel is

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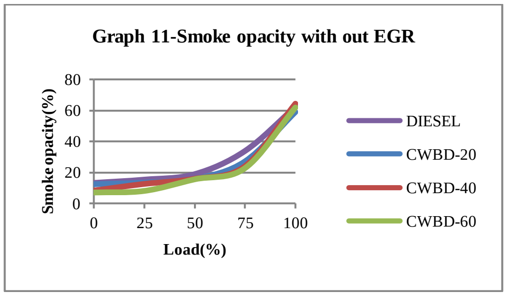
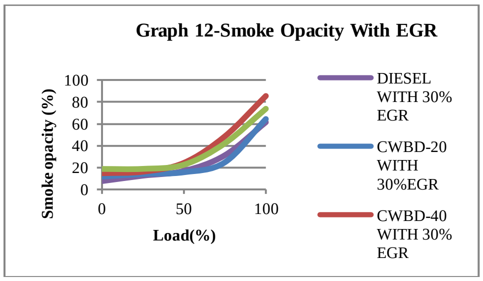
injected into the combustion chamber and hence incomplete combustion of fuel is amplified. Reduction of smoke emissions for biodiesel based fuels in comparison to diesel fuel has been achieved for all load conditions. With an increase of biodiesel blends, smoke decreases [4,14] at most of the operating Conditions. The reduction in smoke can be explained by the presence of less carbon with biodiesel based fuels as compared to diesel. In addition to that, biodiesel has more oxygen content contrary to diesel, which has no oxygen. The presence of oxygen in the biodiesel is in favor of carbon residual oxidation, which leads to reduction in smoke opacity. The smoke is produced mainly in the diffusive combustion phase, the addition of oxygenated fuel such as biodiesel leads to an improvement in diffusive combustion. This factor leads to the improvement of combustion quality for blends when compared to diesel fuels. it was found that smoke opacity decreases more at higher loads than lower loads.





VII. CONCLUSIONS

Engine performance and emissions were found to be comparable when using biodiesel made from chicken waste or a combination thereof rather than diesel fuel. Chicken waste biodiesel and its mixes reduced BTE by roughly 3-9% compared to diesel. Using an EGR (exhaust gas recirculation) system or other suitable mechanism will help minimize the oxides of nitrogen produced by chicken waste biodiesel and its mixes, which were greater than diesel fuel at all loads. Emissions like carbon monoxide (CO), smoke density (SD), and hydrocarbons (HC) were decreased while using biodiesel and its blends in place of diesel. It's possible that full combustion of fuel is responsible for these lower emission levels. According to the findings, biodiesel made from chicken waste has the potential to serve as a viable alternative to diesel in the future, particularly in the areas of agriculture, industry, and transportation where high levels of energy consumption are expected. Biodiesel made from chicken waste and its mixes can be utilized in a standard diesel engine with no adjustments needed due to similar engine performance and reductions in UBHC, CO, and smoke opacity compared to diesel fuel. However, future research can focus on optimizing suitable blend with regard to engine specifications.

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