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Experimental Investigation on the Behaviors of CI Engine Fueled with DEE Additive Blended for Chicken Fat Oil as a Biodiesel

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***Abstract*—The world now has a secure alternative thanks to the use of biodiesel. It has the potential to reduce dependency on conventional diesel fuel in addition to being a renewable energy source. Additionally, the use of additives can assist with some technical problems caused by the use of biodiesel fuel. There are a huge number of benefits that petrol additives offer. Oxygenated additions raise the cetane rating and combustion quality. Ethers, alcohols (such as butanol, methanol, and propanol, etc.), and alcohols (such as ethyl tert-butyl ether, methyl tert-butyl ether, Di isopropyl ether, dimethyl ether, diethyl ether, etc.) are the most widely used oxygenate additives. The alcohols ethanol and diethyl ether (DEE) are excellent diesel substitutes or a means to reduce dependency on it. The results showed that the DEE additives decreased the viscosity of the biodiesel while increasing its oxidation stability and certain number. A Kirloskar diesel engine has been used in the experiment under varying loads. In this experiment, diesel has been employed as the baseline reading. A combination of 20% chicken fat and methyl ether (B20CFME) and B20CFME + methyl ether with varying fuel ratios (5%, 10%, and 15%) are used for testing. The engine was subjected to loads ranging from 0% to 100%, and the outcomes were assessed, tallied, and plotted on graphs for discussion. Utilizing this additive therefore lowers emissions without affecting combustion characteristics.**

With reductions in unburned hydrocarbons of 11.5%, NOx of 6.69%, CO emissions of 0.0425Vol%, improvement in heat releasing rate (HRR) of 10.19%, and peak pressure of 4.217% at full load, the B20CFME + DEE15% showed improvement in all the examined parameters. This endeavor, which almost had an economic impact, simultaneously addressed the issues of fossil fuels and air pollution on a global scale.

***Index Terms*— Chicken fat biodiesel, DEE, HRR, Peak Pressure, Emission characteristics.**

I. FUEL BLENDS DESCRIPTION

B20CFME- 20% CFME and 80% diesel
B20CFME+DEE5% - 20% CFME and 80% diesel + 5% diethyl ether

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B20CFME+DEE10% - 20% CFME and 80% diesel + 10% diethyl ether
B20CFME+DEE15% - 20% CFME and 80% diesel + 15% diethyl ether

II. INTRODUCTION

According to the International Energy Agency (IEA), the oil market predicted a 1.3% growth in oil consumption in 2019 [1]. Petroleum-based fuels are more expensive and produce harmful byproducts as CO, NOx, CO2, and PM, which increases greenhouse gas levels. Due to the potential advantages of biodiesel, these factors inspire scientists and researchers to look for other sources. Biodiesel is produced using long chain fatty acids from vegetable or animal fats. Although biodiesel is the best alternative for CI engines and has characteristics similar to those of diesel, it cannot be used directly because it contains triglycerides, necessitating the transesterification process to produce biodiesel that complies with ASTM standards. Among other unfavorable traits, biodiesel has a higher density, a higher viscosity, and a lower heating value. Chemicals are utilized to alter these unfavorable circumstances. These additives will raise the quality of the biodiesel such that it satisfies international pollution guidelines [1]. DEE mixes will produce less NOx, emit less CO2, and minimize smoke than pure diesel due to an increase in O2 [2].
M. Kirubakaran et al. [3], This paper addresses the use of animal fats for energy production, notably leftover chicken fat, the benefits of using chicken fat for biodiesel production, several methods for extracting oil from chicken fat, and various biodiesel manufacturing processes. A thorough analysis of the application of innovative heterogeneous such as organic and metal-based catalysts for the transesterification process. The details of the variables impacting transesterification parameters, including molar ratio, catalyst weight percentage, reaction time, and temperature, were gathered from many research articles. Additionally, various co-solvents used to boost methyl ester conversion are studied in the transesterification reaction. In-depth assessments of relative optimization methods used to transesterification process parameters have also been covered. It has become clear that waste chicken fat, which is both more readily available and less expensive than virgin vegetable oils, has the potential to serve as a feedstock for the generation of high-quality biodiesel. The extraction time can be shortened and the most oil can be extracted from chicken fat using the microwave oven method. While homogeneous catalysts NaOH, KOH, CH3OH, and CH3OK have been used for transesterification as cost-effective catalysts, sulphuric acid has been widely used for esterification to reduce high free fatty acid levels. It has been established that the optimal substitute for alcohol in the transesterification process is a novel acyl acceptor like ethyl acetate.
Guru, M et al [4], in this study, the effects of using chicken fat biodiesel with synthetic Mg addition on engine performance and exhaust emissions were examined in a single-cylinder, direct injection (DI) diesel engine. The synthesis of the biodiesel was decided upon as a two-step catalytic method. The reaction involved the use of methanol, sulfuric acid, and sodium hydroxide catalyst. Reaction temperature, methanol ratio, type, and amount of catalyst were all altered independently to examine their impacts on the biodiesel's viscosity and flash point. 12 μmol of a synthetic magnesium additive with an organic base was added to the biodiesel mixture. Engine experiments were conducted using diesel fuel (EN 590) and a 10% chicken fat biodiesel/diesel fuel blend (B10) under full load conditions and at various engine speeds between 1800 and 3000 rpm. The findings revealed that while the specific fuel consumption increased by 5.2% as a result of biodiesel's lower heating value, the engine torque did not change appreciably with the addition of 10% chicken fat biodiesel. The in-cylinder peak pressure increased somewhat, and combustion began sooner. NOx emissions increased by 5%, but CO emissions reduced by 13% and 9%, respectively.

II. MATERIALS USED AND METHODOLOGY

This section describes the biodiesel production process, the characteristics of the tested fuels, and the experimental apparatus.

A. Biodiesel and its Preparation

Transesterification was determined to be the most efficient and cost-effective of the four basic methods for producing biodiesel. Alkalis, acids, or enzymes can catalyze Transesterification processes. The catalytic transesterification of chicken fat with methanol is an important industrial technique in biodiesel synthesis. Methanolysis is a well-developmental process that uses potassium hydroxide or sulphuric acid as a catalyst. However, such catalytic complexes will be inactive for long-chain alcohols. Potassium, sodium hydroxide, or potassium methoxide is commonly used as catalysts for this reaction because they are both cost-effective and active. The catalytic esterification method is divided into acid and alkaline esterification processes based on the acid content of waste cottonseed and chicken fat oils. If the acid value of chicken fat exceeds 2.5mg KOH/g oil, two-stage esterification methods (acid and alkaline) are utilized; if the acid value is less than 2.5mg KOH/g, only the alkaline esterification process is used. Figure.1 depicts the entire functionality of the transesterification process. Diesel, CFME, and DEE fuel properties were determined and evaluated to meet ASTM standard standards. Table 1 summarizes the properties of the tested biofuels.

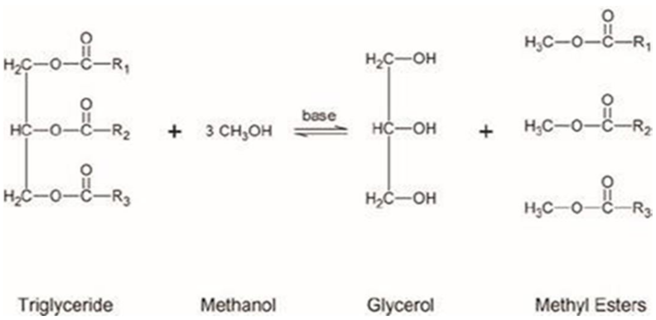

Fig.1 Chemical process of transesterification of oil

B. Oxygenated additives

Because oxygen is present in oxygenated additives, they are nothing more than fuel. To improve the combustion properties and octane number, oxygenated additives were added. Some oxygenate additives include ethanol (methanol, ethanol, propanol, butanol, and so on), esters (acetoacetic ester and dicarboxylic acid esters), and ether (methyl tert-butyl ether, ethyl tertiary butyl ether, diethyl ether, dimethyl ether, and so on). The oxygenated additives are thought to lower the temperature at which biofuel ignites. However, the amount of smoke reduced by oxygenated additives is affected by the oxygen level and the molecular structure of the fuel. The composition of biodiesel, including additives, influences a number of qualities, including viscosity, density, volatility, low-temperature behavior, and cetane number. Oil may react more effectively with oxygenated components, reducing the amount of gas released into the atmosphere. The engine may burn fuel more thoroughly with oxygenated diesel [6, 7 & 8].

C. Error and uncertainty analysis

There will undoubtedly be flaws and uncertainties in the experimental data due to ambient conditions, experimental test settings, excessive or wrong instrument handling that affects calibration, as well as planning, monitoring, and reading. Because of the inaccuracies, accurate results cannot be achieved. As a result, approaches and tools from mathematics and statistics are used to compensate for these errors. To reduce any potential inaccuracy, the technique frequently entails repeating the experimentation's data (at least three times) and determining the mean. Table 1 shows the results of the uncertainty measures that were computed. The level of uncertainty in the experiment was 1.85%.

TABLE I: ERROR ANALYSIS AND UNCERTAINTY

Measurements	Accuracy	Uncertainty
Speed	±3 RPM	± 0.3%
BSFC	±3 kg/KWh	± 0.35%
Power (KW)	±0.3KW	± 0.40%
CO	±0.02%	± 1.0%
NOx	±7 ppm	± 0.7%
In cylinder pressure	±0.1 bar	± 0.2%
Temperature	±1°C	± 0.1%
HC	±7 ppm	± 0.7%
Torque	± 0.1Nm	± 1%

III. SET-UP FOR AN EXPERIMENT

The experiment was carried out under varied weights with a 3.5kW Kirloskar diesel engine. In this experiment, diesel and four other fuels were employed as baseline values. The engine ran at varied loads on each of the five fuels, and the results were assessed, gathered, and presented on graphs for debate. The properties of the test fuels are shown in Table II.

Fig. 2: Computerized Diesel Engine Test Rig

TABLE II: DIESEL AND BIODIESEL MIXTURES' PHYSICAL AND CHEMICAL CHARACTERISTICS

Particular	**Diesel**	**B20CFME**	**B20CFME+DEE5 %**	**B20CFME+DEE10%**	**B20CFME+DEE15 %**
Kinematic Viscosity (40°C, CST)	3.05	4.47	4.32	4.26	4.12
Heat Value (MJ/Kg)	42.6	40.82	41.12	41.35	41.42
Density (Kg/m^3)	828	831	831	830	830
Flash point °C	60	98	96	95	93
Cetane Number	40	49	50	51	53

IV. RESULTS AND DISCUSSION

Multiple tests under various loads were carried out, and the results were compiled and graphically represented.

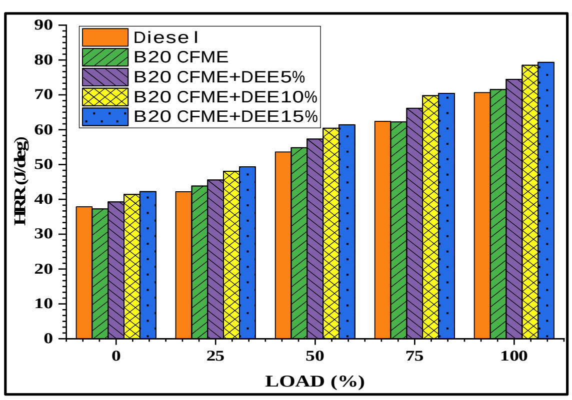

Fig 3: Variation of HRR with Load for diesel, B20CFME and B20CFME+ DEE

Figure 3 depicts the deviation of HRR with load for diesel, B20CFME, B20CFME+DEE5%, B20CFME+DEE10%, and B20CFME+DEE15% samples; among all blend, B20CFME+DEE15% has a higher HRR of 10.19% than diesel and other concentrations. [9, 10]. Because larger loads burn more fuel, resulting in a higher heat release rate, it is also noticeable that HRR values increase significantly with increasing loads. At full load, B20CFME+DEE15% has the highest HRR and Diesel has the lowest. This is because the biodiesel blend's chemical makeup comprises more oxygen molecules with DEE, resulting in a greater HRR than all-tested blends. Premixed combustion is also responsible for the higher HRR of Blend.

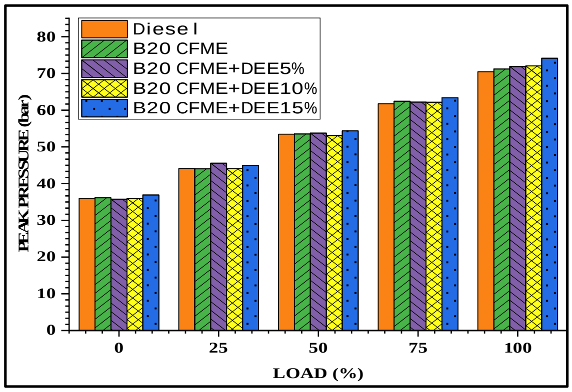

Fig 4: Variation of peak pressure with Load for diesel, B20CFME and B20CFME+ DEE

Figure 4 depicts the variation in peak pressure as a function of engine load for diesel, B20CFME, B20CFME+DEE5%, B20CFME+DEE10%, and B20CFME+DEE15% samples. Peak pressure is increased by 4.21% in B20CFME+DEE15% compared to diesel and all other blends. This evidence reveals that increasing the proportion of DEE in biodiesel blending causes cylinder pressure to rise. The oxygen content of biodiesel has been discovered to be copious, resulting in increased in-cylinder pressure due to increased surface area contact. Additional air and fuel mixtures promote faster fuel burn inside the cylinder. Peak Pressure for B20CFME+DEE15% was 78.87 bars, while B20CFME and diesel were 71.89 bar and 70.67 bar, respectively. Peak pressure rises as a result of its shorter ignition delay and increased viscosity. [11, 12].

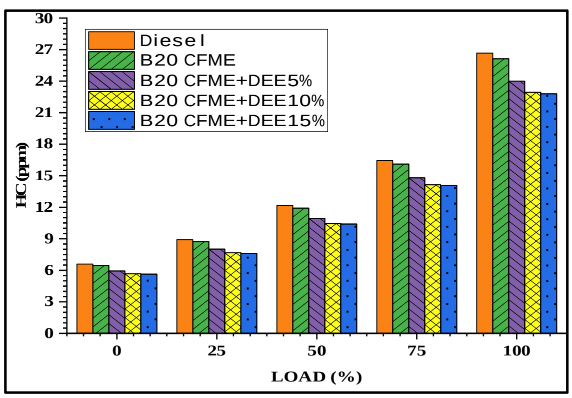

Fig 5: Variation of UBHC with Load for diesel, B20CFME and B20CFME+ DEE

The graph for HC in terms of PPM against varying load in terms of % is shown in Figure 5. The variation in HC emission for diesel, B20CFME, B20CFME+DEE5%, B20CFME+DEE10%, and B20CFME+DEE15% samples with braking power at various loads. The graph demonstrates that the engine produces more HC while operating on diesel than when running on esterified oils under all loading conditions. Methyl esters, which are hydrocarbon chains having an oxygenated terminal at one end, are what make up biodiesel. The oxygen in the biodiesel and DEE mixture promotes an increase in combustion rate, which reduces the hydrocarbon emissions. The HC emission increases when the air-fuel ratio climbs above the stoichiometric value. In comparison to diesel, B20CFME+DEE15% demonstrates an 11.5% reduction in HC. The amount of HC is decreased because the combustion of these denser alcoholic esters and alcohols containing hydrocarbons in their structure takes longer [13, 14].

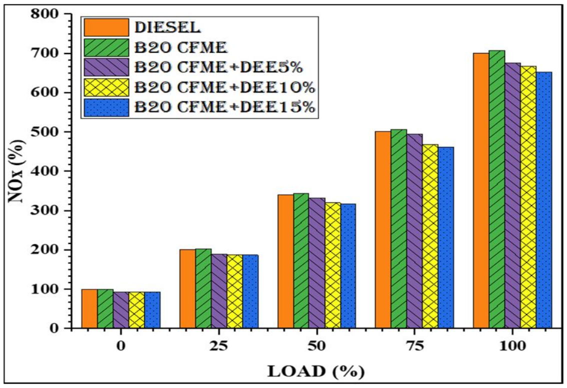

Fig 6: Variation of NOx with Load for diesel, B20CFME and B20CFME+ DEE

The graph of NOx percentage versus varying load percentage is shown in Figure 6. For all of the tested fuels, it can be seen that NOx is lower at partial loads and rising at full loads. Temperature of combustion, oxygen availability, and reaction time all have a significant impact on NOx generation. Figures demonstrate that when using esterified oils rather than diesel, the engine produces greater NOx under all loading conditions. Because biodiesel contains oxygen, combustion proceeds more thoroughly, increasing the temperature at which nitrogen reacts with oxygen to form nitrogen oxides.

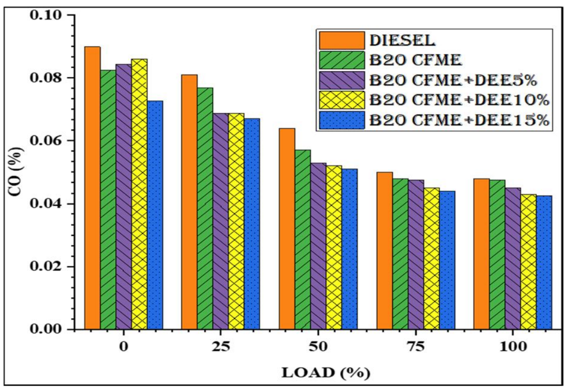

Fig 7: Variation of CO with Load for diesel, B20CFME and B20CFME+ DEE

The variation of CO emission for diesel, B20CFME, B20CFME+DEE5%, B20CFME+DEE10%, and B20CFME+DEE15% samples are shown in Figure 7 as a function of engine load. B20CFME+DEE biodiesel blends exhibited lower CO emission levels than conventional biodiesel blends. This is because biodiesel and diethyl ether have been oxygen-enriched, which may enhance the amount of oxygen that could help oxidise more CO during combustion and make combustion more complete at greater loads. When diethyl ether is oxidised, an OH radical is produced, which is beneficial for converting carbon monoxide into carbon dioxide. A significant amount of the CO produced at maximum loads had been transformed to CO2 (carbon dioxide), which resulted in a decrease in the CO output. B20CFME+DEE15% biodiesel, out of all the investigated blends, displays a reduced CO by 0.0425 Vol% compared to diesel [15, 16].

The contrast between smoke opacity and load for the diesel fuel samples B20CFME, B20CFME+DEE5%, B20CFME+DEE10%, and B20CFME+DEE15% is shown in Figure 8. When compared to diesel, blends with oxygenated additives produce less opaque smoke. For the B20CFME, B20CFME+DEE5%, B20CFME+DEE10%, and B20CFME+DEE15% fuels, the decreased smoke was attributed to better secondary atomization and fuel air mixing. When compared to diesel, B20CFME+DEE15% exhibits a 12.82% decrease in smoke opacity. The DEE enhances combustion, by minimizing ignition delay. [17, 18].

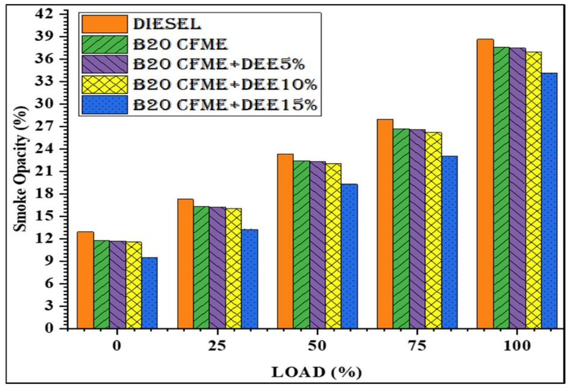

Fig 8: Variation of SO with load for Diesel, B20CFME and B20CFME+ DEE

V. CONCLUSION

This paper investigates the effects of chicken fat methyl ester (CFME) with additions of diethyl ether in the proportions of 5%, 10%, and 15% in order to assess the combustion properties. The findings of the research study are as follows. B20CFME+DEE15% shows the improved HRR of 13.42% compared to diesel and other concentration.

- B20CFME+DEE15% is enhanced by peak pressure 11.64% compared to diesel and all other blends.
- B20CFME+DEE15% shows reduction of the HC compare to B20CFME was 7.22% and 17.75% compare to diesel respectively.
- B20CFME+DEE15% biodiesel shows the reduced CO by 0.031 Vol% compare to diesel
- B20CFME+DEE15% shows the reduced smoke opacity by 7.89% compare to diesel.

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