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EXPERIMENTATION ON DIFFERENT FUEL COMBINATION IN RCCI ENGINE

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……………………………………………ABSTRACT……………………………………………………

In daily life, fossil fuels play an important role in transportation and energy production. As engine emissions increase, fossil fuel consumption also increases rapidly. Both the economy and the environment suffer because of our fossil fuel behaviour. RCCI (Reactivity Controlled Compression Ignition) combustion offers a promising avenue for enhancing fuel efficiency and reducing emissions in internal combustion engines. RCCI (Reactivity Controlled Compression Ignition) engines are designed to make the engine more efficient and reduce emissions by mixing different fuels to increase its efficiency. This study investigates the environmental impact of RCCI combustion utilizing Indian fuel blended with Milkscum biodiesel. Through comprehensive experimentation and analysis, the study assesses the combustion characteristics, emissions performance, and environmental implications of this novel fuel blend. Results indicate significant reductions in greenhouse gas emissions, particulate matter, and other harmful pollutants compared to conventional diesel combustion. Additionally, the utilization of Milkscum biodiesel, derived from sustainable feedstocks, demonstrates potential for mitigating environmental degradation associated with conventional fossil fuels. The findings suggest that RCCI combustion with Indian fuel and Milkscum biodiesel holds promise for fostering a more sustainable and eco-friendly transportation sector, contributing positively to environmental conservation efforts.

Keywords: RCCI, Milkscum, Reactivity, Emission, Combustion, Biodiesel.

1.INTRODUCTION

Reactivity Controlled Compression Ignition (RCCI) engines have emerged as a promising technology in the quest for more efficient and environmentally friendly internal combustion engines. These engines offer the potential to achieve high thermal efficiency while simultaneously reducing harmful emissions such as nitrogen oxides (NOx) and particulate matter (PM). In the context of increasing concerns about climate change and air pollution, RCCI engines represent a significant step forward in addressing these challenges.

However, the widespread adoption of RCCI engines is contingent upon the availability of suitable alternative fuels that can complement their combustion characteristics and enhance their environmental performance. Biodiesel, derived from renewable sources such as vegetable oils or animal fats, has garnered considerable attention as a potential substitute for conventional petroleum-based diesel fuel. In recent years, researchers have explored various feedstocks for biodiesel production, including non-edible oils and waste materials, to mitigate concerns regarding food competition and land use change associated with conventional biodiesel feedstocks.

One such unconventional feedstock with promising potential for biodiesel production is milkscum—a byproduct of the dairy industry. Milkscum, also known as dairy processing waste or whey cream, is a lipid-rich material that accumulates during the production of dairy products such as cheese and yogurt. Traditionally considered a waste stream, milkscum presents an opportunity for valorization through the extraction and conversion of its lipid content into biodiesel. By repurposing this waste material for biodiesel production, not only can we reduce the environmental footprint of dairy processing but also contribute to the production of a sustainable and renewable transportation fuel.

The utilization of milkscum biodiesel in RCCI engines offers several potential advantages. Firstly, milkscum biodiesel can serve as a domestically sourced alternative to petroleum diesel, reducing dependence on imported fossil fuels and enhancing energy security. Secondly, biodiesel derived from milkscum is expected to have lower lifecycle greenhouse gas emissions compared to petroleum diesel, contributing to climate change mitigation efforts. Additionally, the combustion characteristics of milkscum biodiesel may complement the reactivity control strategies employed in RCCI engines, leading to improved combustion efficiency and reduced emissions of criteria pollutants.

Despite its potential benefits, the utilization of milkscum biodiesel in RCCI engines poses several challenges and uncertainties that warrant further investigation. These include the optimization of biodiesel production processes from milkscum, the characterization of biodiesel properties and performance in RCCI combustion, and the assessment of the environmental impacts and economic feasibility of this fuel option. Addressing these challenges requires a multidisciplinary approach that integrates expertise from fields such as chemical engineering, combustion science, environmental sustainability, and agricultural economics.

This introduction sets the stage for a comprehensive exploration of RCCI engines fueled with milkscum biodiesel, aiming to elucidate the technical, environmental, and economic aspects of this novel fuel option. Through a thorough review of existing literature, experimental investigations, and techno-economic assessments, this research seeks to advance our understanding of the potential of milkscum biodiesel as a sustainable fuel for RCCI engines. By identifying opportunities and addressing challenges, this study aims to contribute to the development of cleaner and more efficient transportation technologies for a greener future.

2.EXPERIMENTAL SETUP

The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Electric start Diesel engine connected to eddy current type dynamometer for loading. Thanks to the specially designed inclined cylinder block arrangement, the compression ratio can be changed without stopping the engine and changing the combustion chamber geometry. The lamp is equipped with the necessary equipment for combustion pressure and crank angle measurement. This signal is connected to the computer through the measurement engine of the PO-PV diagram. Provision has also been made for the connection of air flow, gas flow, temperature measurement and load measurement. The set up has stand-alone panel box consisting of air box, two fuel tanks for blend test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameters are used for water cooling and water calorimetry measurement.

The setup can examine VCR engine performance with EGR, including braking power, indicated power, friction power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, fuel consumption rate, A/F ratio and thermal balance. Provide Labview-based engine performance analysis software package "Enginesoft" for online performance evaluation.

Computerized diesel injection pressure gauge optionally available [22]

Fig.2.1: RCCI Engine

Table 2.1: Specifications of Engine

Product	VCR Engine test setup 1 cylinder, 4 stroke,Diesel with EGR (Comp.)
Product code	234
Engine	Make Kirloskar, Type 1 cylinder, 4stroke Diesel,water cooled, power 3.5 kW @1500rpm, stroke 110mm, bore 87.5mm. 661cc, CR 17.65. Modified CR 12-18(special case CR 12-22). Electric start arrangement.
VCR arrangement	CR adjustment is made with the following special functions The compression ratio can be adjusted on the fly without engine shutdown. Tilting roller mechanism.
Dynamometer	Type eddy current, water cooled
Propeller shaft	With universal joints
Air box	MS fabricated with orifice meter and manometer
Fuel tank	Fuel metering column has a capacity of 15 litrers and made of glass
Calorimeter	Type Pipe in pipe
EGR	Water cooled, SS, Range 0-15%
Piezo sensor	The cable operates quietly within a range of 5000 PSI.
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Piezo powering unit	Model AX-409.
Temperature transmitter	Type RTD, PT100 and Thermocouple, TypefK
Temperature sensor	RTD PT100, Range 0-100°C,3 Nos; Thermocouple, Range 0-1200 °C, 2 Nos
Load indicator	Digital, Range 0-50 Kg
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	"EngineSoft" Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Pump	Type Monoblock
Overall dimensions	D 2500 x W 2000 x H 1500 mm
Optional	Computerized Diesel injection pressure measurement with injection variation 0-25 deg BTDC

Features

• CR changing without stopping the engine

• No alteration in Combustion chamber geometry

• Water cooled EGR

• Electric start with battery and charger

• Arrangement for blend test

• PO-PV plots, performance plots and tabulated results

• IP, IMEP, FP, indication combustion analysis

Range of Experiments

• Study of VCR engine performance (Computerized mode)

• Study of emissions with EGR variation

• Study of combustion with different fuel blends

Utilities Required

Electric supply

230 +/-10 VAC, 50 Hz, 1 phase

Computer IBM compatible with standard configuration

Water supply

Continuous, clean and soft water supply @ 1000 LPH, at 10 m. head. Provide tap with 1" BSP size connection.[22]

3.FUEL SAMPLE

3.1 Milkscum (Biodiesel)

During the heating process, a layer often forms on the surface of the milk. Foam is a white, low density substance that is usually composed of a mixture of oils, proteins, lipids and other substances. The transesterification process reacts methanol with triglyceride fat found in milk residue to produce fatty acid methyl esters (biodiesel) and glycerol as by products.

3.2 Raw Material

Milk residue is the waste product of dairy products obtained from waste water treatment (water purification method) and contains lipids, fats and protiens. The waste is collected from a dairy factory which produces around 200-300 kg of waste ecery day.[7] Foa, contyains large amount of oils and other oils. The apperance of milk filter foam oil is orange as shown in figure 2.

Fig.3.1: Waste Milkscum & Scum Oil

3.3 Method of Preparation of Biodiesel:

The principle of biodiesel production is the transesterification process as .All oils are tested for FFA (free fatty acids) before the transesterification process. Titration is performed with KOH and phenolic measurement to determine the acid number of the dung oil FFA value was found to be 2.495. A two stage transesterification process is applied to reduce the amount of oil in the foam oil (Ali and Taya 2013; Sudheer et al. 2007). Preparation of Biodiesel Foam oil biodiesel is prepared by the esterification method (two steps) .Due to the high FFA value, a two stage transesterification method (acid esterification method) should be used. During the esterification reaction, heat the 11 oil mixture to 50°C, add 150ml methanol and 2% H_2SO_4 and stir at a speed of 65°C for about one and a half hours. After the reaction, the drug was left in a separate location for 24 hours. Figure 5.1. Diagram of the test engine and alternator. Energy, Part A: Consumption, Use and Environmental Impacts 3Surface formation occurs. The resulting upper layer consists of excess alcohol along with sulfuric acid and removed impurities. In the second stage, the subprocess is used (Blaco and Paiva et al. 1996; Fukuda, Kondo and Noda 2001; Zehng and Kates 2006) (alkaline esterification). In the base catalyzed esterification reaction, the product of the first step is heated again from 65 to 70 °C. To this mixture was added 6.5 g NaOH dissolved in 150 ml methanol and stirred for one and a half hours. After the reaction is completed, the solution is left to stand for another 24 hours. Glycerin is at the bottom and the esterified oil mixture rises to the top. The esterified oil mixture is separated and washed with warm water. After purification, the final product is heated to 120°C for 30 minutes and then cooled to room temperature. Thus, the scum oil biodiesel is obtained .[7]

Table 3.1: Biodiesel Properties

Serial No	Properties	Scum Oil	Protocol
1	Viscosity at 40 C	3.7	ASTMD445
2	Specific gravity	0.87	ASTM6751
3	Calorific value (kj/kg K)	39,940	ASTM D5865
4	Flash point (C)	132	ASTM D93
5	Fire point (C)	150	ASTM D92
6	Cloud point (C)	4	ASTM D2500

4.RESULTS AND DISCUSSIONS

Brake Thermal Efficiency

Performance of any engine is evaluated based on its brake thermal efficiency for the obtained power output. Figure 6 demonstrates distinct blends the variety of heat brake efficiency (BTE) with load. It is observed that the behavior of BTE trends curve increases with increase in load at CR = 18. It is found that BTE of diesel is at 50% load is 19.34 ppm and when milkscum is blended in the ratio of B15, B20, B25, B30 it shows 24.3%, 24.21%,24.21%, 23.32%. BTE of diesel is at 75% load is 21.73 ppm and when milkscum is blended in the ratio of B15, B20, B25, B30 it shows 32.36%, 32.61%,32.53%,33.1%. BTE of diesel is at 100% load is 20.38 ppm and when milkscum is blended in the ratio of B15, B20, B25, B30 it shows 34.29%, 34.15%,34.06%,34.2%. From above B15 gives better results.

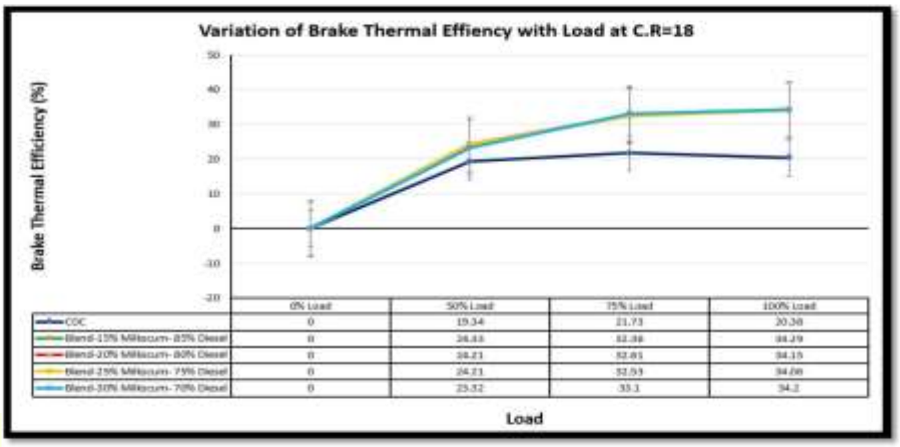


Fig.4.1: Variation of Brake thermal efficiency with load C.R=18

Brake Specific Fuel Consumption

The variation of specific fuel consumption with regard to load is shown in Figure 7. BSFC drops for all fuel blends as the load rises. B25 at advanced injection timing of 5deg BTDC indicates the lowest fuel consumption at a full load and is 0.24 kg / kWh. The BSFC of the B30 blends when injection is advanced 5deg BTDC is 0.26 kg / kWh at full load, whereas it is 0.39kg / kWh for diesel. The BSFC is dropping at a larger proportion of blends. This can be due to the fuel density, viscosity and heating value. B20's power content is greater than B15.

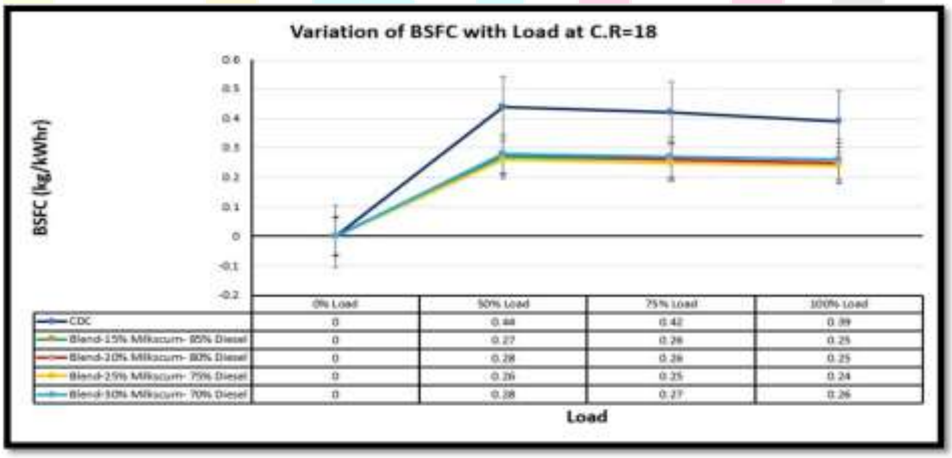


Fig.4.2: Variation of BSFC with load C.R=18

Brake Power

The variation of load with respect to BP at CR=18 is shown in Fig. 4. The load shows the amount of energy released by a burning unit mass of fuel while producing unit kW Brake power. The Brake power was found to be lowest for diesel fuel compared to other fuels. The Brake power values were found to be 1.8, 2.55, 3.26 KW for diesel and milkscum B15, B20, B25 and B30 are 3.45, 3.43, 3.4 and 3.41 respectively at 100% load capacity. This Blend has lower calorific value, higher density and higher viscosity of biodiesel when compared to diesel fuel.

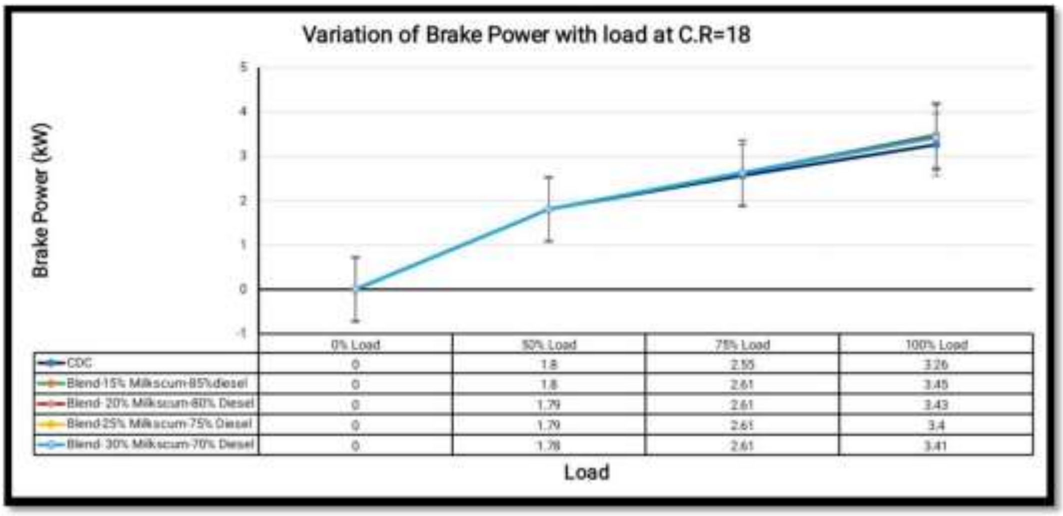


Fig.4.3: Variation of Brake Power with load C.R=18

CO Emission

The CO emission for different fuel blends with respect to load is shown in Figure 6. The decreased CO emissions of test fuels was found with increase in loads, also lower CO emissions are found with all the milkscum biodiesel blends in comparison to diesel due to the presence of higher intrinsic oxygen content and less C/H ratio of in milkscum biodiesel that causes complete combustion. The better result is given by B15 at every load variations while other blending get increased the CO emission rate.

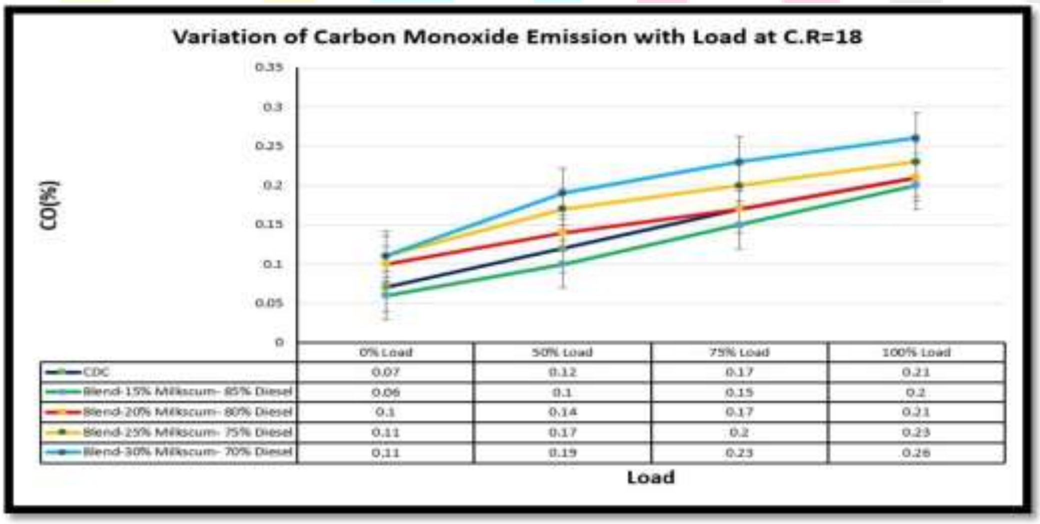


Fig.4.4: Variation of Carbon monoxide emission with load C.R=18

Smoke Capacity

From the above figure we can observe that the smoke opacity goes on escalating with the load. As compared to diesel, the B15 blend at 50% load tends to have higher accessibility to oxygen which results in better combustion of the fuel and hence compared to diesel, B15 at advanced injection timing has lower smoke opacity of 8.5%, B30 has 10% and a to diesel 7.4%.

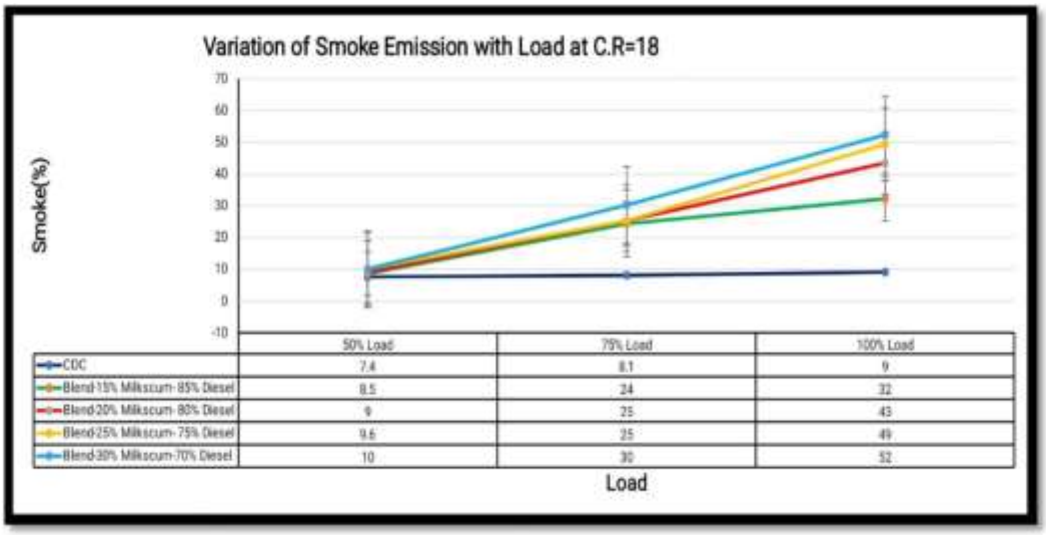


Fig.4.5:Variation of Smoke emission with load C.R=18

NOx Emission

The Figure 10 depicts the variation of NOx with the loads. Since formation of NOx is clearly a temperature dependent phenomenon. NOx emission increases with the increase in loads and due to the rise in exhaust gas temperature in the combustion chamber. The NOx emission for milkscum and blend B15, B20, B25, B30 comparing with diesel for full load is 398 ppm, 365 ppm 322ppm and 304 ppm respectively for standard engine condition. The reduction of NOx has been observed by altering the injection timing. The advancement of injection timing reduces NOx by B30 are 19, 90 and 304 at load capacity of 50%, 75% and 100% respectively.

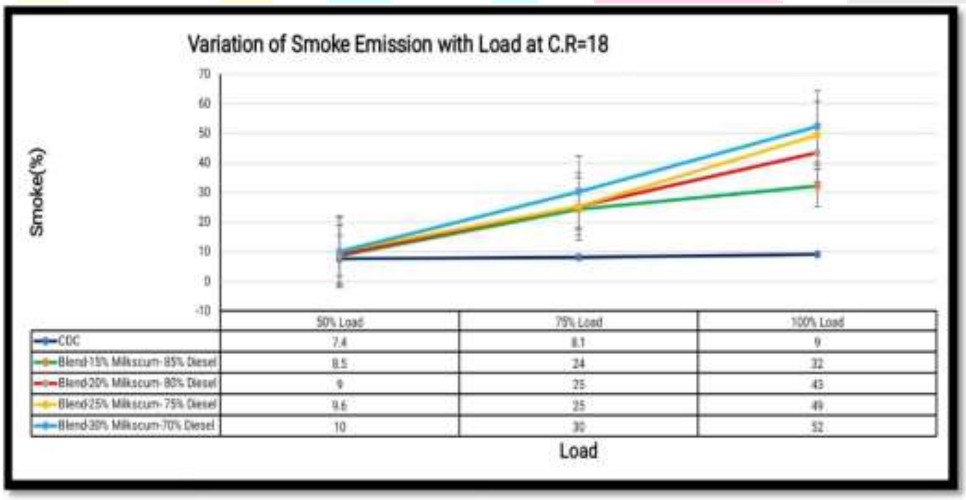


Fig.4.6:Variation of Oxides of nitrogen with load C.R=18

HC Emission

From Figure11 we can conclude that with the increase in the loads, there will be decrease in the hydrocarbon emissions. Fuel-rich combustion, crevice flows, valve overlap, misfiring and flame quenching desorption of hydrocarbon cause HC emission. Diesel has the highest HC emission when we compare the biodiesel blends. In case of milkscum B10 the HC emissions is much more lower because of the higher oxygen content which results in complete combustion thereby reducing the emissions. From the graph we infer that B15 and B20 decrease the HC emission at any load variation.

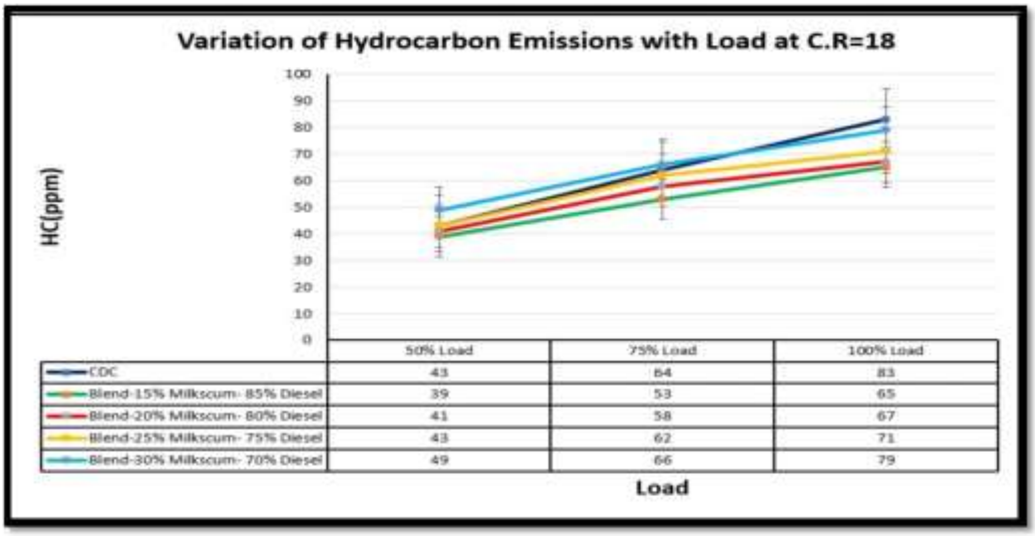


Fig.4.7: Variation of Hydrocarbon emission with load C.R=18

CO2 Emission

From Fig. 6, it witnessed that the emission of CO_2 decreases with an increase in BP and with higher biodiesel content in the blends. The reason for the increase in CO_2 emission percentage is due to more oxygen content of biodiesel leading to complete combustion. The CO_2 emissions were found to be 2.8, 2.3, 2.2, 2.1 and 1.8 correspond to diesel and B15, B20, B25 and B30, respectively at 50% load capacity. The CO_2 emissions were found to be 4, 2.5, 2.4, 2.3and 2.2 correspond to diesel and B15, B20, B25 and B30, respectively at 75% load capacity. The CO_2 emissions were found to be 6, 5.5, 5, 5.3and 4.5 correspond to diesel and B15, B20, B25 and B30, respectively at 100% load capacity.

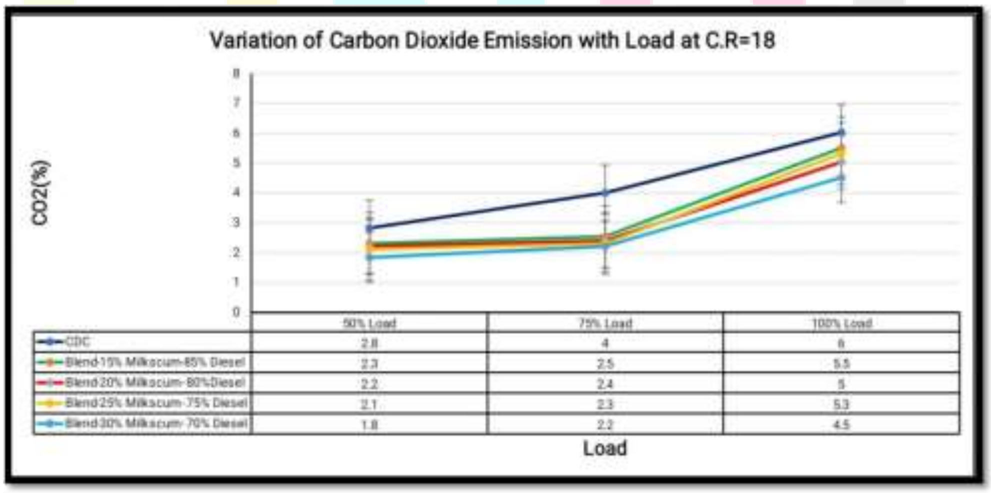
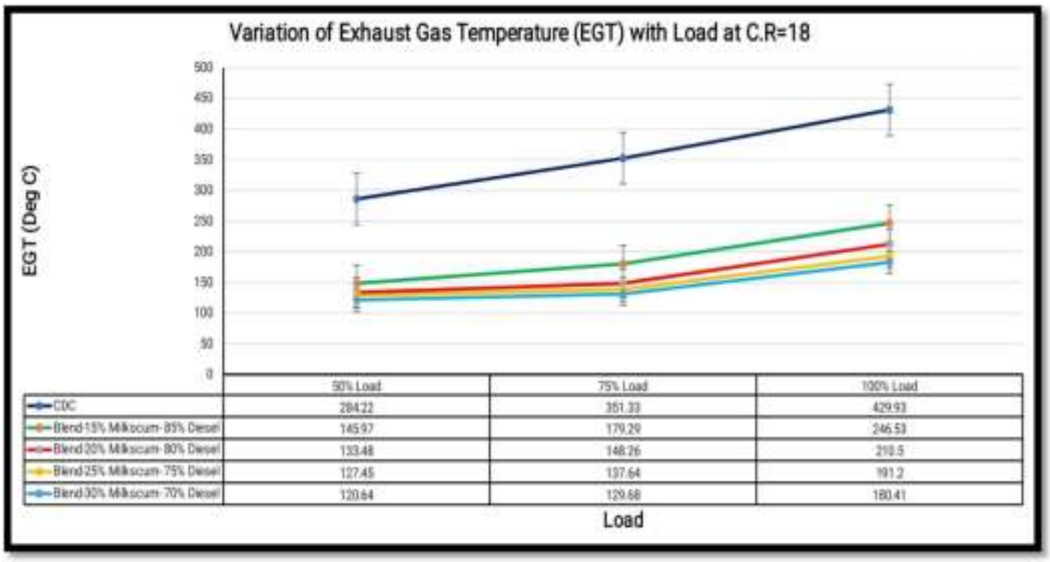


Fig.4.8: Variation of Carbon dioxide with load C.R=18

Exhaust Gas Temperature

It shows changes in EGT under different conditions. The EGT was decrease with increase in load with all the test fuels. The decreased EGT was due to improved combustion of fuel due to enhanced atomization at warmed-up condition results in the rise in EGT with the increase in load. Also, the EGT found to be decreased with the increase in the concentration of biodiesel in the blends; this is due to increase in oxygen content in the fuel blends as biodiesel contains more intrinsic oxygen which accelerates the combustion process resulting in higher EGT by B30 are 120.64, 129.68, 180.42 at every load variation.



	50% Load	75% Load	100% Load
CDC	284.22	351.33	429.93
Blend-15% Milkscum-85% Diesel	145.97	179.29	246.53
Blend-20% Milkscum-80% Diesel	133.48	148.26	210.5
Blend-25% Milkscum-75% Diesel	127.45	137.64	191.2
Blend-30% Milkscum-70% Diesel	120.64	129.68	180.41

Fig.4.9: Variation of Exhaust gas temperature with load C.R=18

5.CONCLUSION

The present experimental research work includes the, characterization followed by performance, combustion and emissions characteristics analysis of RCCI engine fuelled with biodiesel blends. The results of the study summarized as follows:

• The engine performance characteristics such as brake thermal efficiency increases with B15 in comparison with diesel. This was due to the inherent oxygen content in fuel which leads to complete combustion of fuels.

• Brake power is increases with B15 in comparison with Diesel and BSFC is decreases with B25 in comparison with diesel.

• Emission characteristics such as Carbon monoxide (CO) and hydrocarbons (HC) emission decreases with B15 in comparison with diesel at 3.5 kW Brake power.

• NOx emission was decreases with B30 in comparison with diesel at 3.5 kW Brake power.

• Smoke emission was increases with B15 in comparison with diesel at 3.5 kW Brake power.

• CO2 emission was decreases with B15 in comparison with diesel at 3.5 kW Brake power.

• Exhaust gas temperature of B30 is less to that of diesel.

From the above discussions, it can be concluded that, Milkscum biodiesel blends is a potential alternative fuel for RCCI engines with satisfactory emission, combustion, and performance characteristics. Hence, Milkscum biodiesel blends can be a potential substitute for fossil diesel fuel.

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