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EFFECT OF CHANGE IN INJECTION PRESSURE ON HYDROGEN ENRICHED MICROALGAE BIODIESEL IN CI ENGINE

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ABSTRACT

Injection parameter such as fuel opening injection pressure has a significant impact on engine combustion, performance, and emissions. For each loading condition of 30%, 60%, 80%, 90%, and 100%, respectively, micro algal biodiesel blends of 30% ($MA30H_2$) were used, along with injection parameters and a fixed hydrogen flow rate of 7 lpm. The goal of this endeavor is to make single-cylinder diesel engines more efficient and less polluting. There are also two great substitutes for traditional fuels that can reduce energy usage and abide by strict emission regulations: hydrogen and biodiesel. A total of three different opening injection pressures 220, 240, and 260 bar will be used in the experiment. Due to its high calorific value, hydrogen enrichment enhances BTE and BSFC and reduces emissions like HC, CO, and CO_2. However, due to a rise in EGT, NOx emission has increased. With the addition of hydrogen, combustion properties such as in-cylinder pressure (ICP), heat release rate (HRR), and ignition delay (ID) improve while the combustion duration (CD) drops.

Keywords: Diesel engine, Biodiesel, Hydrogen, Injection pressure

INTRODUCTION:

Rapid population growth and socioeconomic development have increased global energy demand. Currently, about half of the carbon dioxide emitted when burning fossil fuels is not absorbed by plants and oceans but remains in the atmosphere, causing global warming [1-2]. Internal combustion engines are widely used in the transportation industry due to their efficiency and versatility. In the field of transportation, diesel engines are very dominant thanks to their ability to generate more torque when operating with a high compression ratio than gasoline engines. Diesel engines emit low concentrations of unburnt hydrocarbons and carbon monoxide compared to spark-ignition engines because diesel engines operate on a very poor air/fuel mixture [3-6]. The main pollutants emitted by diesel engines are unburnt hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), particulates (PM), sulfur oxides (SOx) and lead. These pollutants cause human health problems and also affect the environment, like climate change, global warming, acid rain, ozone depletion and photochemical smog, etc. Because oil reserves are limited to certain regions, the rest of the world has to import fuel from those regions to meet its energy needs [7-9]. Since conventional hydrocarbon fuels are finite in nature and non-renewable, they could be completely depleted or lead to a major global crisis when demand outstrips supply. The depletion of fossil fuels, increasing fuel costs and environmental degradation due to emissions have generated strong global interest in the development of renewable fuels to replace conventional fuels [10,11].

The present work aims to reveal possible combinations of operating parameters to achieve higher power output and lower emissions. Therefore, in this experimental study, we attempt to evaluate the effect of open injection pressure of a constant-speed diesel engine operating at full load using microalgae-based biodiesel fuel. and hydrogen.

EXPERIMENTATION:

Present work will be done on a water-cooled single-cylinder CRDI four-stroke diesel engine with rated speeds and outputs of 3000 rpm and 9 hp respectively. Figure.1 shows line of experimental equipment. CRDI engines are equipped with various components such as high-pressure fuel pump, pressure regulator, common piping, rail pressure sensor and fuel injectors. The pressure sensor is connected to the electronic control unit (ECU). For charging, a water-cooled eddy current dynamometer is used. A crankshaft angle sensor is mounted on the crankshaft to measure the crankshaft angle. The pressure in the cylinder is measured by a piezoelectric pressure transducer mounted on the cylinder head. The data acquisition system receives pressure signals, monitoring combustion parameters including heat release rate and cylinder pressure. The temperature of the inlet and outlet water, fuel, engine oil, intake air and exhaust gases of the diesel engine used are measured with a type K thermocouple. To measure the exhaust gas temperature (EGT), the sensor pair The thermoelectric is located on the exhaust pipe near the cylinder. A 5-gas AVL analyzer is installed to monitor emissions such as carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NOx), as well as a smoke meter to measure smoke. On the other hand, pressure regulators, flow meters, hydrogen cylinders, flow control valves, flame arresters and fire traps are all part of the hydrogen supply line. The pressure vessel maintains a high pressure of 250 bar for hydrogen then reduces it to 2 bar using a pressure regulator. Hydrogen is then supplied to the cylinder at a rate of 7 lpm by a flow meter and control valve. Hydrogen is routed through the flame arrester. It also performs the function of a check valve.

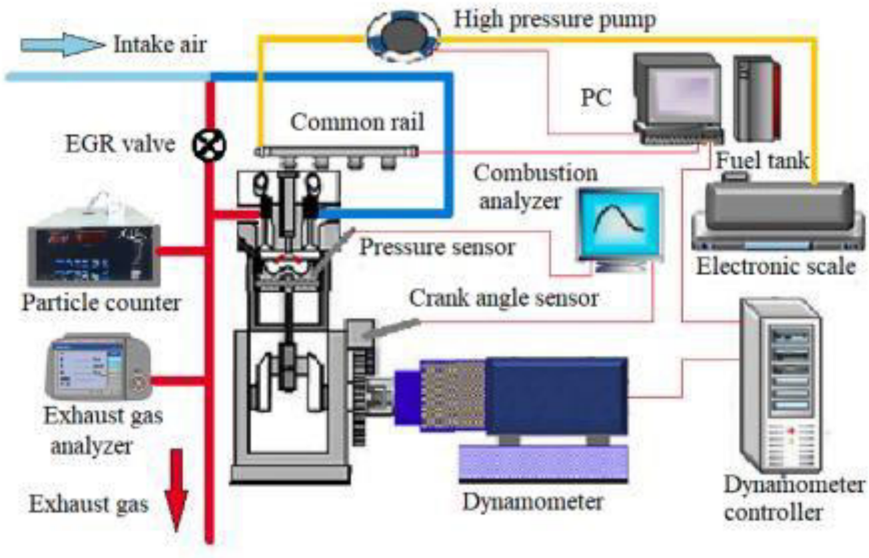


Figure 1: Experimentation Line Diagram

Table: 1. Physico-chemical Properties of Microalgae Biodiesel

Fuel Property	Biodiesel ASTM(D6751)	Diesel Fuel ASTM(D975)	MME
Density (Kg /m3)	860 - 900	820 - 860	876
Cetane Number	Min.47	40 - 55	46
Calorific Value(Kj/Kg)	-----	42000-46000	38945
Kinematic Viscosity @ 40°C (mm^2 /S)	1.9 – 6.0	2.6 – 5.7	5.32
Flash Point (°C)	Min.130	60 - 80	178

Table 2. Specifications of the Test Rig

S.No	Description	Specifications
1	Make	Mahindra and Mahindra
2	Engine Capacity (cc)	625
3	Number of cylinders	1
4	Application	Automotive (Multi-speed)
5	Number of Strokes	4
6	Compression Ratio	18:1
7	Bore (mm)	93.0 to 93.018
8	Stroke Length (mm)	92
9	Ignition	Compression Ignition
10	Max. Power @ RPM	9 HP @ 3000 RPM
11	Max. Torque @ RPM	30 NM @ 1800 RPM
12	Cooling System	Water Cooled

RESULTS AND DISCUSSIONS

Emission Characteristics:

Carbon monoxide (CO):

Carbon monoxide emissions are caused by incomplete fuel combustion, which depends on many parameters such as the air/fuel ratio and engine temperature. **Figure.2** shows the CO emissions of fuel B30 at 1200 rpm with a hydrogen flow rate of 7 l/min at 0% EGR, 10% EGR, 20% EGR respectively. These results suggest that CO emissions can be reduced by using more biodiesel in the fuel mix, especially at lower engine speeds. This fact is mainly due to the presence of oxygen in the chemical formula of biodiesel. This excess oxygen makes it possible to convert CO to CO_2, resulting in reduced CO emissions. At higher engine speeds, where the volumetric efficiency of the engine during intake is less, the role of this excess oxygen in the mixed fuel appears to be more effective. Therefore, the high-quality biodiesel produced in this study had a significant impact on CO emissions, as shown in Fig.2

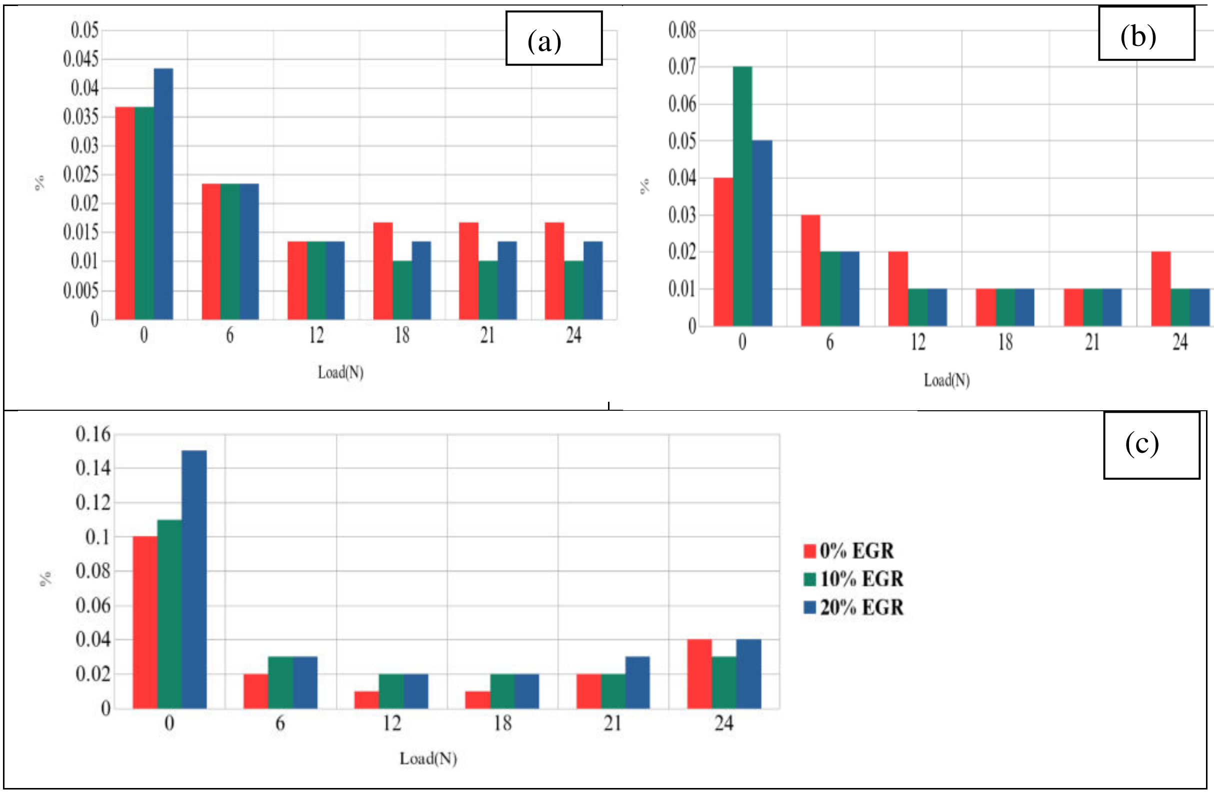
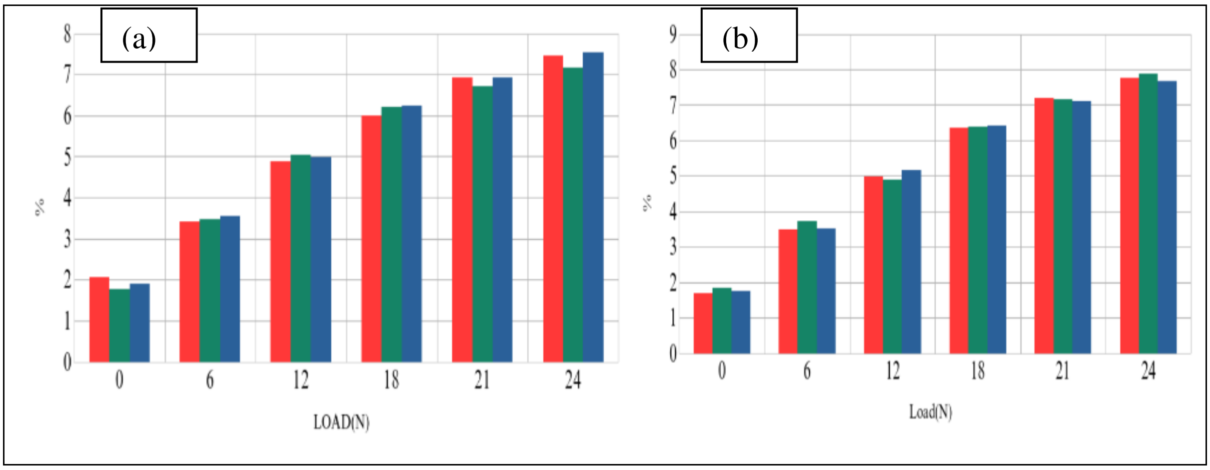


Figure 2: CO emissions at various EGR's & loads for injection pressure at (a) 220bar (b) 240bar (c) 260bar of B30 Micro-Algae biodiesel at 7 lpm Hydrogen flow rate

Carbon dioxide (CO2)

The CO2 emission for B30 fuel at different loads and EGR's with an engine speed of 1200 rpm at 7lpm hydrogen flow rate are illustrated in Figure 3. The figure establishes that at 24N of load , the CO2 emissions at 10%EGR is lesser by 0.34% with 20%EGR and is lesser by 0.27% in comparison with 0%EGR respectively. These increases are due to the oxygen content of biodiesel fuel, and consequently, the more complete combustion process of fuels comprising biodiesel compared to pure diesel fuel.



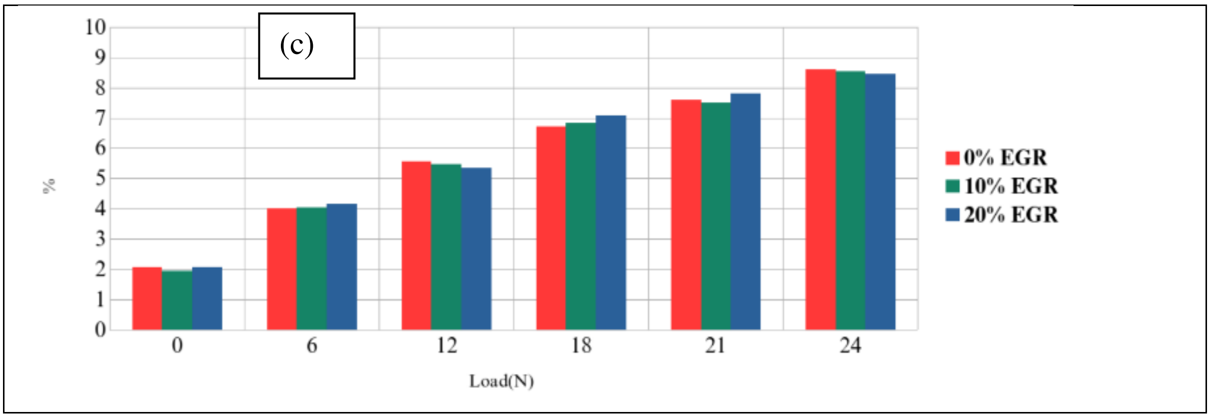


Figure 3: CO_2 emissions at various EGR's & loads for injection pressure at (a) 220bar (b) 240bar (c) 260bar of B30 Micro-Algae biodiesel at 7 lpm Hydrogen flow rate

Hydro Carbon (HC):

The HC fraction value in the exhausted gases of an engine is a parameter for evaluating the fuel combustion quality; it increases when the fuel combustion process is less complete. Figure 4 shows the HC emissions for B30 fuel at 7lpm hydrogen flow rate at different loads and EGR's of the engine. The results show that averagely 4.71% and 18.53% HC reductions in the exhaust gases occurs for B10 and B20 in comparison to pure diesel at 600 rpm, respectively; at 900 rpm, these average values are 7.75% and 18.14%, and at 1200 rpm they are 9.50% and 18.18%, respectively. The decrease in the temperature of combustion and the lack of sufficient oxygen to assist combustion completeness are the reasons for the existence of unburned HC in the combustion products. Due to the oxygen content of biodiesel fuel, blended fuels lead to less HC pollutant fraction than pure diesel.

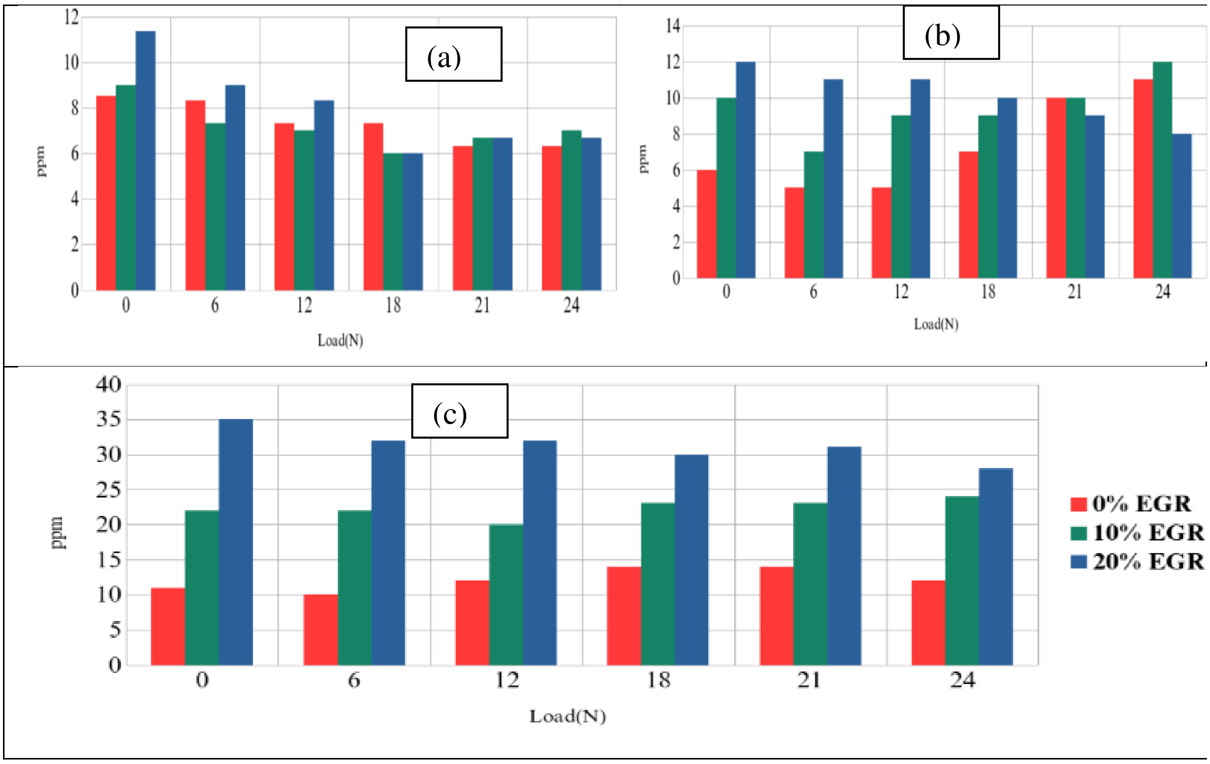


Figure 4. HC emissions at various EGR's & loads for injection pressure at (a) 220bar (b) 240bar (c) 260bar of B30 Micro-Algae biodiesel at 7 lpm Hydrogen flow rate

Nitrogen Oxides (NOX):
The NOx emissions for the investigated fuels under different operational conditions of the engine are presented in Figure 5. The average values of data presented in Figure 5 shows that the NOx emissions at the loading stages are almost equal in 0%EGR and 10%EGR respectively. At 24N Load 20%EGR emits less NOx than 0%EGR. NOx production is a function of combustion interval in 2p crank angle (the shorter the combustion interval, the less NOx is produced). Also, the fuel cetane number is inversely related to combustion delay (i.e., the larger the fuel cetane number, the less combustion delay).

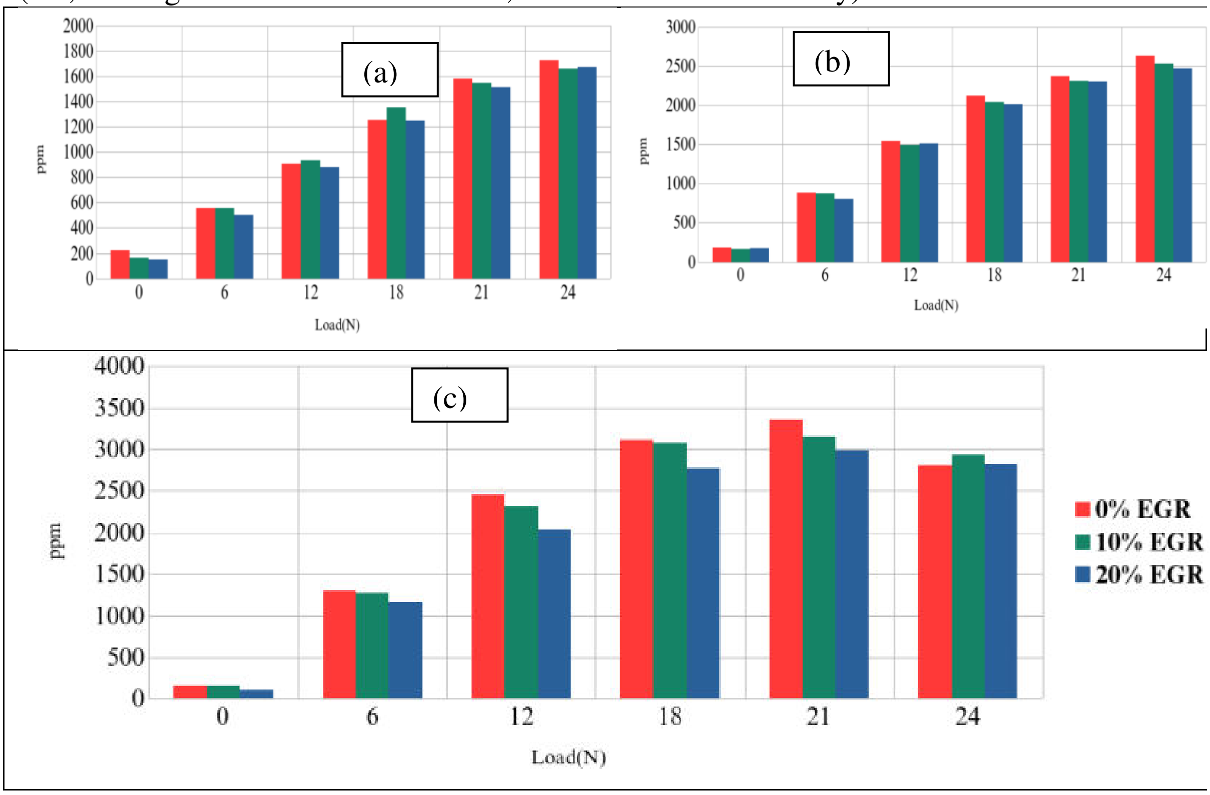


Figure 5: NOX emissions at various EGR's & loads for injection pressure at (a) 220bar (b) 240bar (c) 260bar of B30 Micro-Algae biodiesel at 7 lpm Hydrogen flow rate

Performance Characterstics:
Brake-specific fuel consumption (BSFC):
Brake-specific fuel consumption (BSFC) is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft power. The brake specific fuel consumption of the engine depends on the rotational speed, compression ratio, gear ratio, engine volume, etc. By increasing the rotational speed of the engine, fuel consumption decreases, due to the reduction chance for heat loss. After it reaches its lowest level, it increases due to the enormous friction losses at higher speeds. The effect of the engine load on the BSFC is the same as the effect of the engine speed on the BSFC. Figure 6 shows the variations of engine BSFC by the engine speed and engine load for the three investigated EGR's. As it is evident in this figure, BSFC is decreased drastically when load is added to the biodiesel fuel, which stems from the less calorific value of biodiesel (44920 kJ/ kg) relative to the pure fuel (45,500 MJ/kg). More specifically, for 0%EGR, 10%EGR and 20%EGR, the BSFC values are atmost equal at a loading stage of 24kg respectively. respectively. At 1200 rpm, the value of BSFC at 24kg is averagely 264 g/kWhr which is lesser than pure diesel.

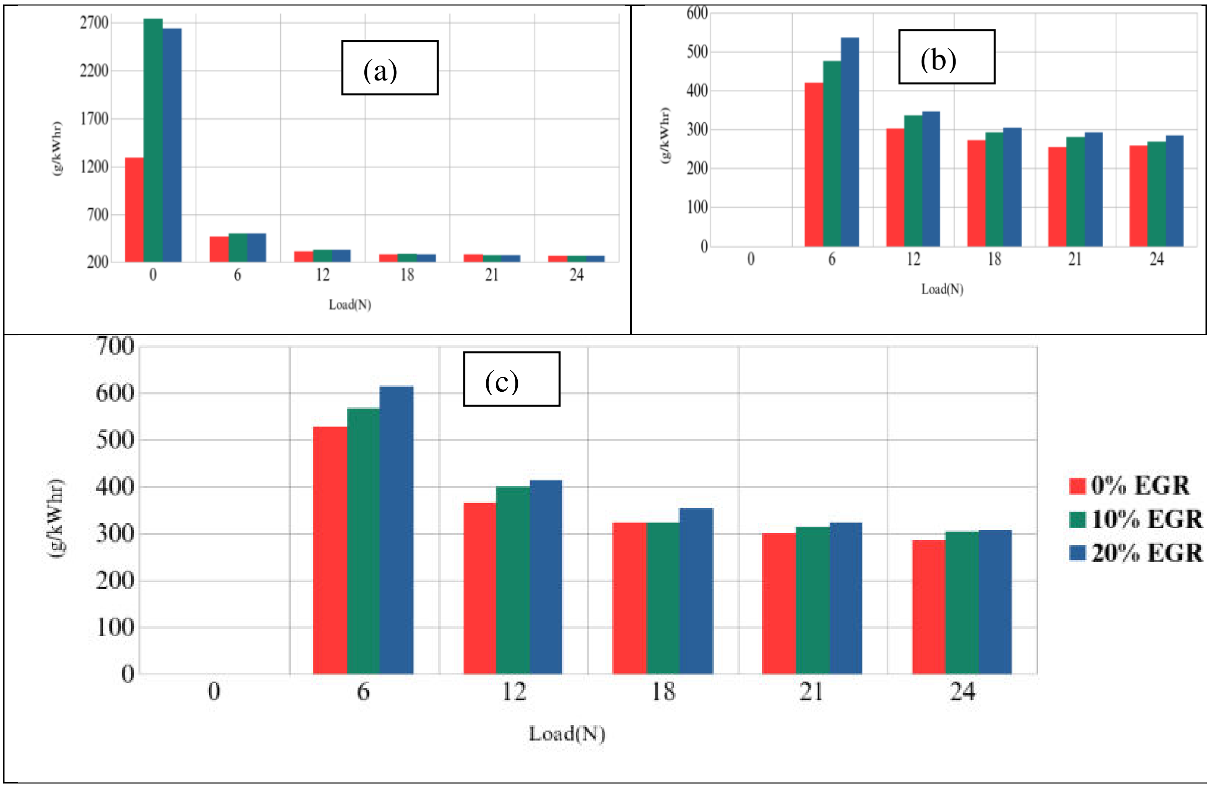
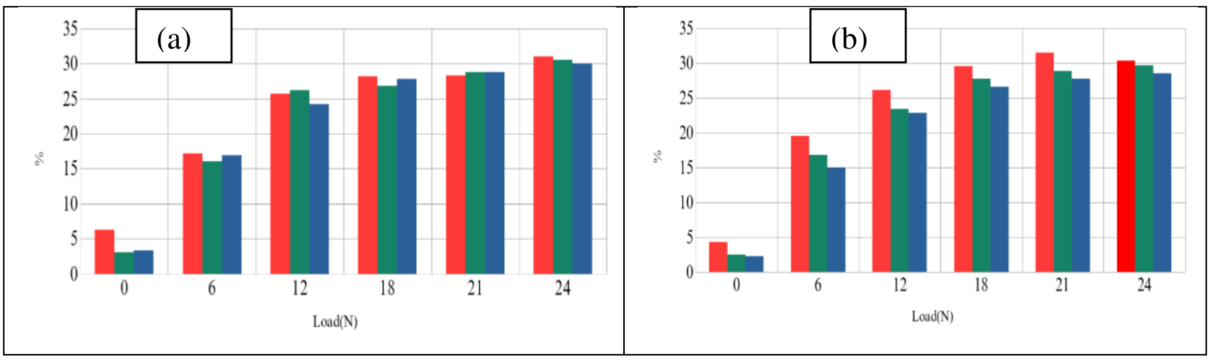


Figure 6: BSFC emissions at various EGR's & loads for injection pressure at (a) 220bar (b) 240bar (c) 260bar of B30 Micro-Algae biodiesel at 7 lpm Hydrogen flow rate

Brake thermal efficiency (BTE):

Brake thermal efficiency is a crucial parameter in evaluating the performance of an engine and is commonly used to assess the efficiency of alternative fuels, including biodiesel. Biodiesel is composed of fatty acid methyl esters (FAMEs), which have different properties compared to conventional diesel fuel. The molecular structure of FAMEs affects their combustion characteristics, such as ignition delay, combustion duration, and heat release rate, which in turn can impact brake thermal efficiency. Additionally, factors such as engine load, speed, injection timing, and injection pressure can also affect brake thermal efficiency in biodiesel. Biodiesel has higher oxygen content, which can result in more complete combustion and potentially higher brake thermal efficiency. From the Figure 7 cited below the brake thermal efficiency lies around 30% - 35% at 0%,10% and 20% EGR's respectively.



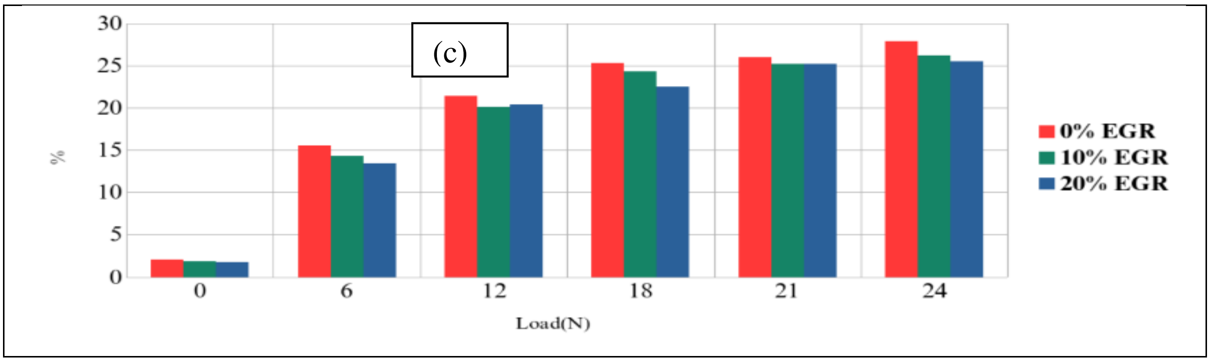


Figure 7: BTE emissions at various EGR's & loads for injection pressure at (a) 220bar (b) 240bar (c) 260bar of B30 Micro-Algae biodiesel at 7 lpm Hydrogen flow rate

CONCLUSION:

The experimentation is carried out for B30 micro-algae biodiesel at various loads 0,6,12,18,21,24 N at 7lpm flow rate of hydrogen and various EGR's 0,10,20 % with an injection pressure at 220,240 and 260 bar before TDC. The results are enrolled as follows:

1. The BTE is higher at 220bar with 0% EGR and slightly less with 10% EGR compared to 0% EGR
2. The BSFC is low at 220bar with 0% EGR and 10% EGR which is good thing NOx emissions are way less at 220bar. CO, CO2, and HC are reduced in 220bar.
3. Overall, using 220bar without EGR is way much better than other angles as it has higher efficiency, low fuel consumption, low NOx, CO, CO2 and HC emissions.

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