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EXPERIMENTAL STUDIES ON A DIRECT INJECTION DIESEL ENGINE FUELED WITH HYDROGEN ENRICHED GARCINIA GUMMI-GUTTA BIODIESEL

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ABSTRACT. Petroleum derivatives are the primary source of energy consumption on a global scale. There exist several limitations associated with the use of fossil fuels, including their finite supply, escalating costs, and the production of pollutants upon combustion in engines. The present investigation experiments were carried out utilising fuel blends: Garcinia Gummi-Gutta Biodiesel 20 (GGGBD20) and hydrogen-enriched GGGBD20. The hydrogen flow rates were evaluated at three levels: 2 lpm, 4 lpm, and 6 lpm, respectively. The result of the experimental investigation focuses on multiple performance, combustion, and emission indicators such as BTE, BSFC, CP, NHRR, CO, UHC, NO_x, and smoke opacity. Additionally, there was an increase in the combustion characteristics relating to the CP and NHRR. In the case of GGGBD20 with 6 lpm hydrogen, the BTE, CP, NHRR, and NOx emissions exhibited a notable increase of 20.26%, 14.99%, 30.99%, and 82.59%, respectively, in comparison to diesel. Other parameters, BSFC, CO, UHC, and smoke opacity showed a reduction of 28.12%, 92.71%, 56.25%, and 61.29%, respectively, in comparison to diesel.

KEY WORDS: Diesel engine, Garcinia gummi-gutta biodiesel, Hydrogen, Biomass biorefinery, Energy consumption

INTRODUCTION

Diesel fuel is essential, as it can supply a substantial quantity of energy that can be used to meet a variety of daily needs, including the movement of manufactured goods, raw materials, and individuals. The global supply of diesel fuel is dwindling, making the development of alternative fuels a top concern. Owing to the rapid depletion of crude oil resources, concerns about global environmental pollution, and an increase in fuel prices [1]. The most cost-effective oil sources for biodiesel production are biodiesels obtained from non-edible plant sources that often grow in arid regions and have no human use. Biodiesel produced from non-edible oil sources may be blended with diesel. When diesel and biodiesel blends are used in diesel engines, exhaust pollutants such as CO, UHC, and smoke opacity are drastically reduced [2]. The IC engine can employ these mixtures in either an electronic or manual version. This prompts the development of the new dual-fuel engine [3]. With this tactic, fuel consumption and exhaust emissions are reduced. To boost engine efficiency and reduce emissions, electrical

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systems must be supported in addition to mechanical system improvements [4]. They operated engines on canola biodiesel to examine combustion, performance, and emissions characteristics. According to their research, when engine load increased, BSFC increased and BTE reduced, while increasing the blend ratio increased NO_x emissions and lowered smoke emissions for all loads [5]. They investigated the effects of operating parameters revealed that the higher thermal efficiency and produced more NO_x than diesel [6]. It shows that the resulting in decreased NO_x emissions using waste biodiesel operated diesel engine [7].

They fuelled CI engines with Juliflora biodiesel and examined performance, combustion, and emission characteristics.They noticed that B20 performance and combustion characteristics were like diesel fuel. Blends B20 and B30 had a BSFC closer to diesel at full load. Juliflora biodiesel blends had slightly less CO, HC, and smoke emissions than diesel [8]. They investigated the possibility of enhancing the efficiency of a conventional diesel engine by including H_2/O_2 mixture levels and we maintaining a constant tempo during the experiment [9]. They investigates the goal of the current research was to use hydrogen-enriched air to increase the mahua oil-fuelled diesel engine's performance. The use of Mahua oil combustion with different hydrogen gravities enriched air, improving brake thermal efficiency and decreasing smoke density [10]. They use Mahua oil was discovered to burn more quickly when hydrogen was added. When mahua oil was operated with hydrogen enrichment, the NO content was greater than when diesel was used. When operating at full load and with a 50 lpm hydrogen induction, the engine let out a loud bang. When hydrogen was added, the smoke density was much decreased, but the noise level rose as hydrogen admittance increased [11].

Many see biodiesel's utilisation as a tool to support rural development, as it opens new markets for agricultural products and lowers fossil fuel consumption. On the other hand, biodiesel produced will function similarly to traditional diesel while offering a highly affordable and environmentally secure substitute. Although the market is only getting started, it is anticipated to grow quickly in South Asia because of rising environmental pollution concerns and a shortage of energy sources.

EXPERIMENTAL

Biodiesel production process

Then the blend was centrifuged for 13 to 16 mins to Prior, FAME GO (biodiesel) was abundantly miscible with petroleum diesel. To examine the miscibility different ratios of biodiesel was mixed with raw diesel and it was checked for 20–25 days, after this there were no changes were observed (Figure 1).

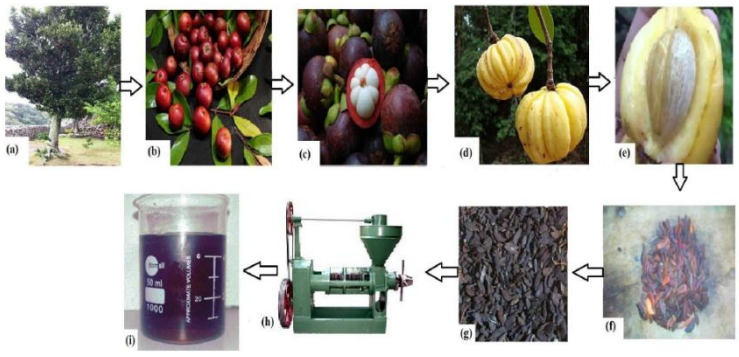


Figure 1. Preparation of biodiesel.

Experimental set-up

For the experiments, engine with a single cylinder, two valves, and water cooling was utilised. The engine rotated at a constant 1500 rpm. Direct injection of biodiesel was made into the combustion chamber of the engine. The injection's duration did not alter. One component of the test stand's measurement system is a dynamometer. Figure 2 shows a schematic of an engine-equipped test stand.

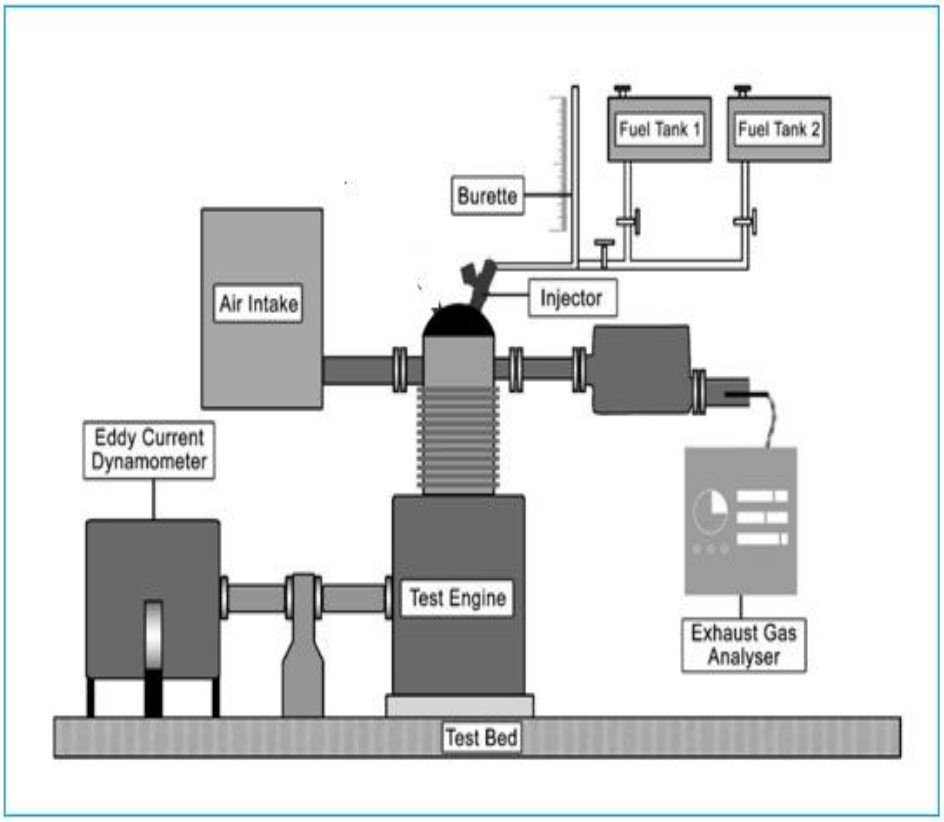


Figure 2. Experimental set-up.

RESULTS AND DISCUSSION

BTE – hydrogen enriched GGGBD20

Figure 3 shows the BTE fluctuation with load. GGGBD20 has a lower BTE than diesel. The drop in BTE of GGGBD20 is the result of its improper fuel atomisation, delayed ignition delay period, lower CV, and higher kinematic viscosity. In contrast, the hydrogen-enriched GGGBD20 has a higher BTE than diesel and GGGBD20, revealing a favourable relationship between hydrogen flow rate and BTE. The observed behaviour may be the result of improved fuel-air mixture homogeneity. The utilisation of a premixed charge consisting of air and

hydrogen has been observed to enhance the flame propagation, thereby leading to improved combustion within the engine. This, in turn, has a positive impact on the BTE of the engine [12].

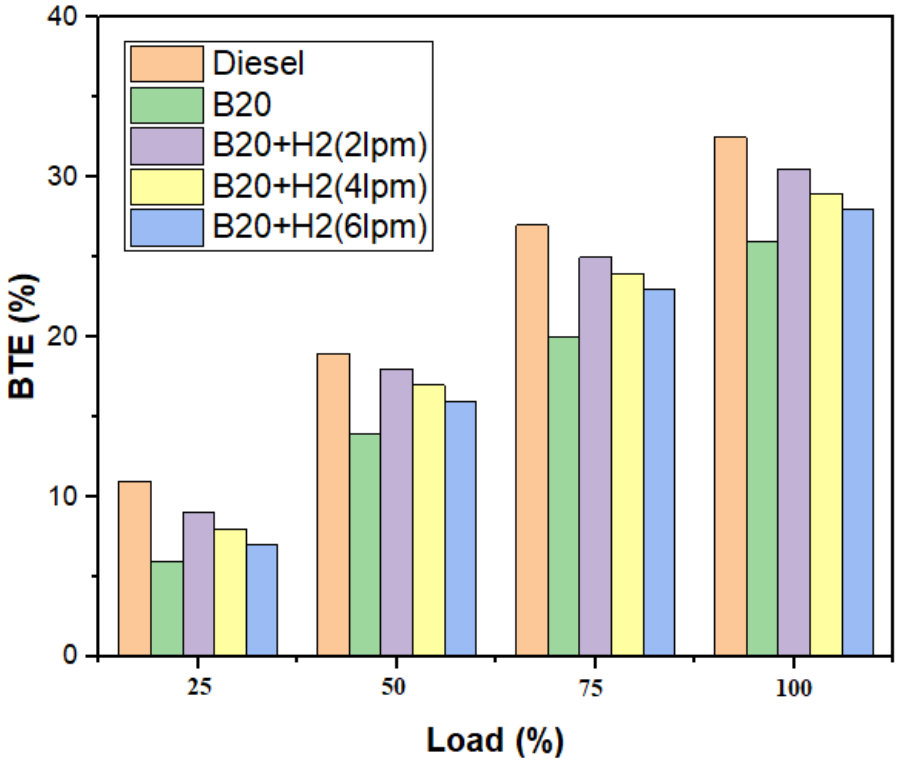


Figure 3. BTE with load.

BSFC – hydrogen enriched GGGBD20

Figure 4 shows the BSFC variation with load. GGGBD20 has a greater BSFC than diesel, as the lower heating value of GGGBD20 leading to a higher fuel flow rate for fuel blend density could account for this disparity. On the other hand, it has been observed that the utilisation of hydrogen-enriched GGGBD20 resulted in a notable decrease in BSFC when compared to diesel and GGGBD20. Additionally, it was found that the reduction in BSFC was directly proportional to the increase in hydrogen flow rate. The improved diffusivity and homogeneity in the air-fuel mixture during the intake phase have been found to have a positive impact on BSFC. The enhanced calorific value of hydrogen has been observed that the reduction in BSFC [13].

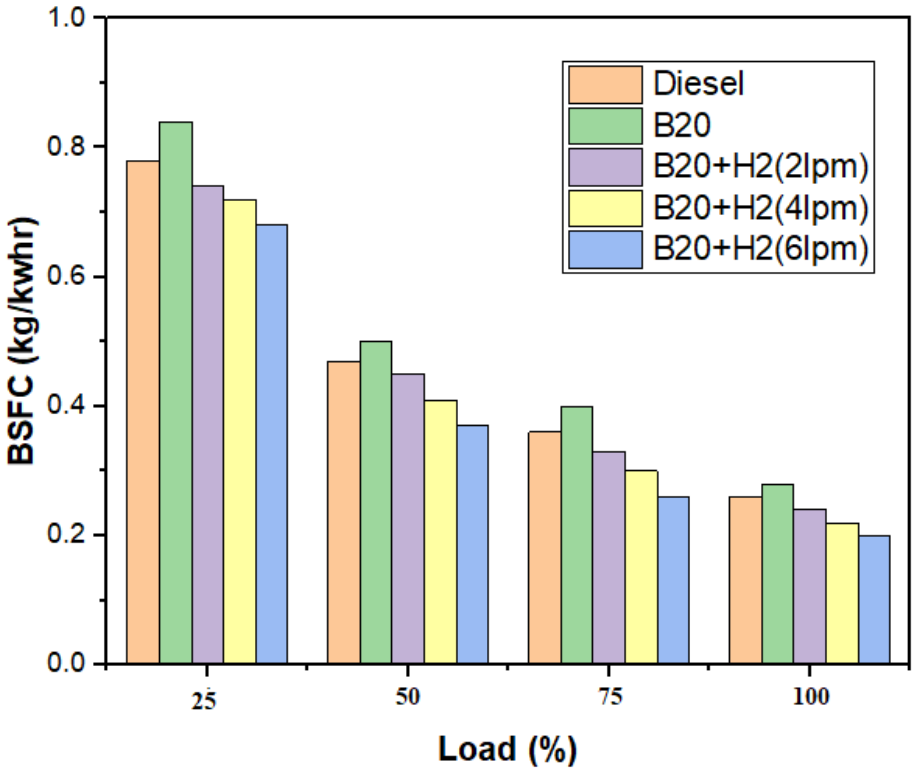


Figure 4. BSFC with load.

CO emission – hydrogen enriched GGGBD20

The data presented in Figure 5 illustrate the variations in CO levels with an increase in load. There is a significant reduction in CO emissions with GGGBD20 due to the presence of oxygen and higher cetane number-led superior complete combustion. The addition of hydrogen to GGGBD20 decrease in CO emissions was observed. The primary factor contributing to this phenomenon is no carbon concentration found within the hydrogen compound. Additionally, it is worth noting that the amount of oxygen intake during suction is replaced with hydrogen, thus reducing oxygen content inside the engine cylinder, leading to reduced CO emissions [14].

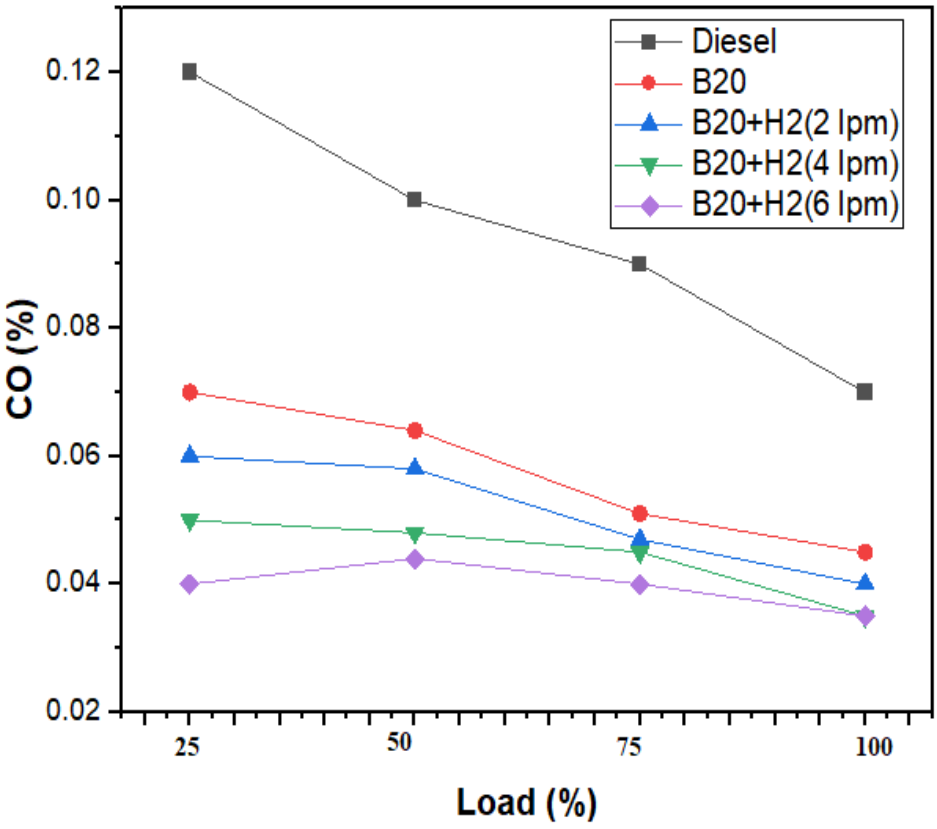


Figure 5. CO emission with load.

UHC emission – hydrogen enriched GGGBD20

The depiction of the relationship between UHC and load can be observed in Figure 6. The UHC emissions have been successfully reduced through the implementation of GGGBD20. The observed behaviour may be related to an increase in combustion efficiency, which can be related to the existence of ideal oxygen levels and a greater cetane number, as shown in previous studies. These fuel mixtures included diesel, GGGBD20, GGGBD20 with an additional 2 lpm of hydrogen, GGGBD20 with an additional 4 lpm of hydrogen, and GGGBD20 with an additional 6 lpm of hydrogen. The measured concentrations of UHC emissions in these fuel mixtures were found to be 101, 65, 56, 49, and 45 PPM. The increase in hydrogen supply has been observed to correspond with a decrease in UHC emissions. Moreover, the UHC emissions were notably reduced due to the effective atomisation achieved at elevated loads [15].

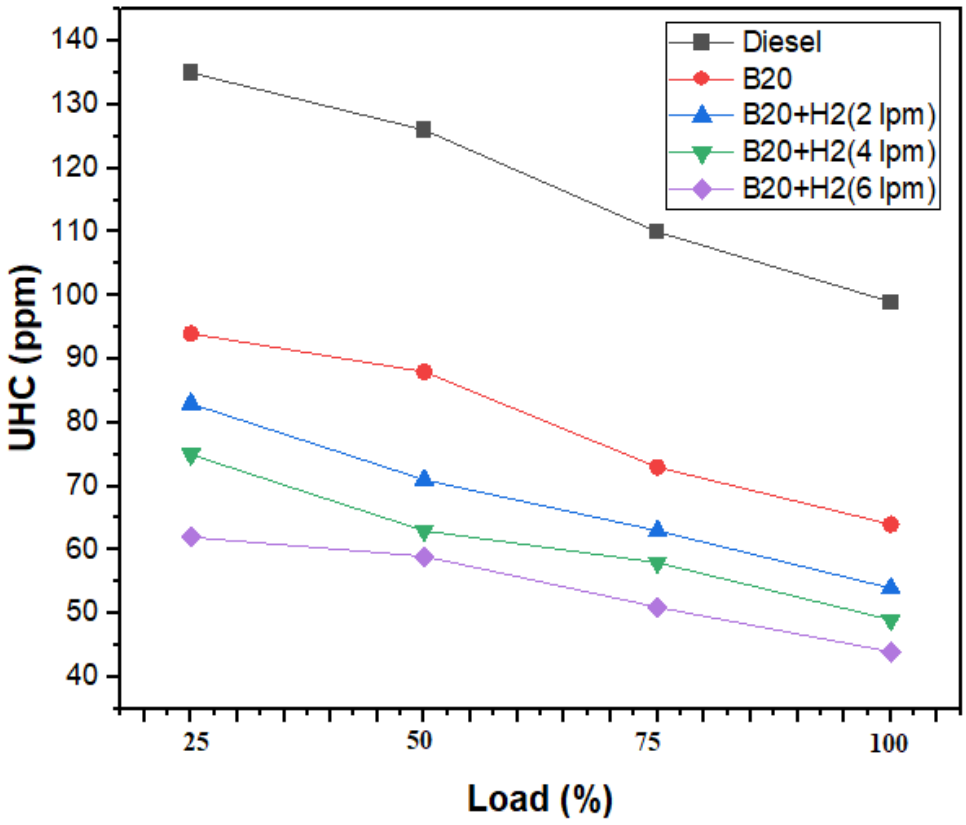


Figure 6. UHC emission with load.

NOx emission – hydrogen enriched GGGBD20

Figure 7 depicted the observed variation in NO_x with different loads. The NO_x was found to be higher when using GGGBD20 compared to diesel. The primary influence of this condition may be traced to the rise in cylinder temperature, which is a direct consequence of the increased rate of combustion. The introduction of hydrogen into the GGGBD20 led to a notable elevation in the amounts of NO_x, which may be related to the increased rate of combustion because of the augmentation of NO_x emissions. The NO_x emissions measured at maximum load fuel blend were as follows: 865 ppm for diesel, 1165 ppm for GGGBD20, 1356 ppm for GGGBD20 with 2 lpm hydrogen, 1621 ppm for GGGBD20 with 4 lpm hydrogen, and 1647 ppm for GGGB20 with 6 lpm hydrogen. An observed correlation has been identified between a rise in load and a subsequent rise in NO_x emissions. This relationship is because of augmented combustion temperatures resulting from the higher load. The observed trend persisted across all fuel blends [16].

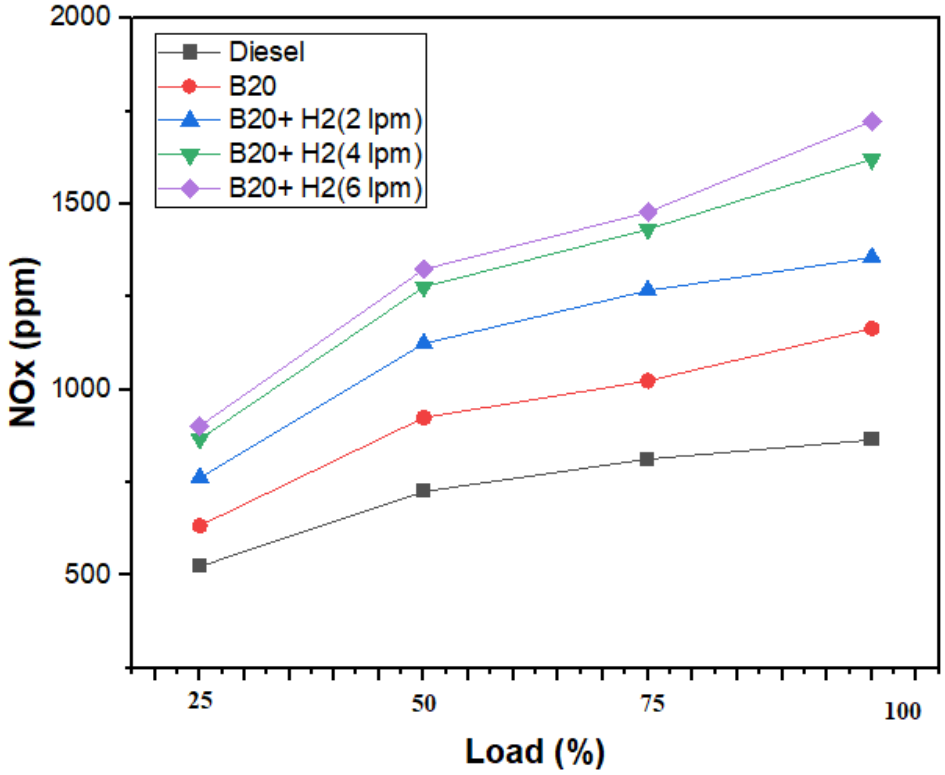


Figure 7. NOx emission with load.

Smoke opacity – hydrogen enriched GGGBD20

The variations in smoke opacity with respect to loads were depicted in Figure 8. The smoke of GGGBD20 was found to be much lower when compared to diesel. The GGGBD20 exhibits a higher combustion capacity because of its elevated oxygen content and superior cetane number. The potential for reducing smoke opacity was anticipated when utilising GGGBD20 with hydrogen due to the improvement in the AF ratio. Higher load was found to be associated with the least amount of smoke opacity. The experimental investigation involved measuring the smoke opacity of various fuel blends: diesel, GGGBD20, GGGBD20 with 2 lpm hydrogen, GGGBD20 with 4 lpm hydrogen, and GGGBD20 with 6 lpm hydrogen load-obtained smoke opacity values were 24%, 17%, 15%, 12%, and 10%, respectively [17].

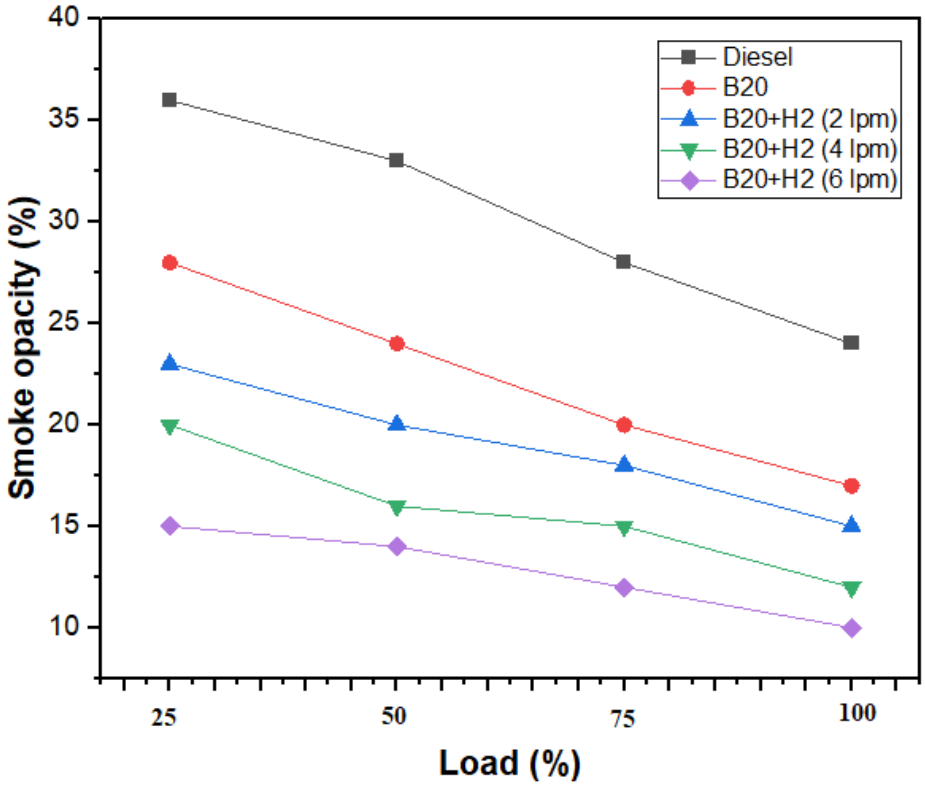


Figure 8. Smoke opacity with load.

CP – hydrogen enriched GGGBD20

Figure 9 depicts the observed variations in CP relative to crank angle. The experimental results suggest that GGGBD20 exhibited a slightly higher CP value compared to diesel. This may be related to the fact that biodiesel exhibits a higher CN and O_2 compared to diesel, which is why there is a higher level of GGGBD20 accumulation within the cylinder and an increased duration of the ignition delay period .The observed increase in fuel accumulation can be associated with a concurrent rise in CP within the engine. Moreover, biodiesel mixture has demonstrated a noteworthy enhancement in CP. The reason for this is the significant quantity of fuel that is undergoing combustion. Similarly, the heightened diffusivity and accelerated flame velocity contribute to enhanced combustion. This may be because of enhanced fuel atomisation resulting in larger fuel droplets [18].

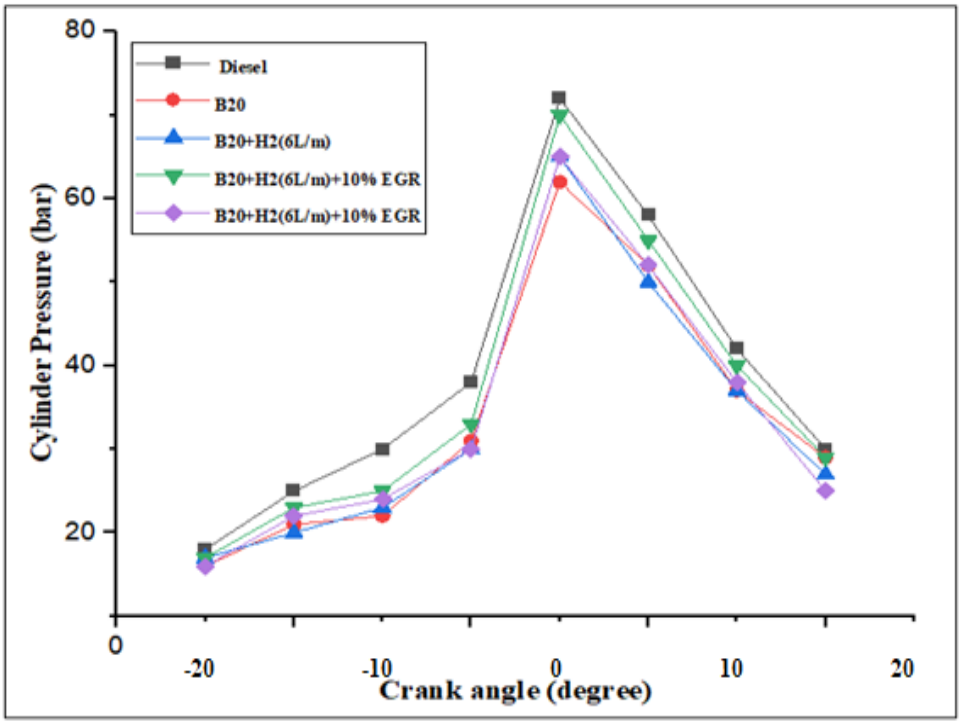


Figure 9. Cylinder pressure with crank angle.

NHRR – hydrogen enriched GGGBD20

The variation of NHRR with crank angle in Figure 10. The NHRR was found to be slightly elevated in the case of GGGBD20 compared to diesel. The observed phenomenon can be attributed to the accumulation of supplementary fuel during the period of delay. Furthermore, it is worth noting that biodiesel exhibits a higher NHRR in comparison to diesel due to two primary factors: its elevated oxygen content and dominant cetane number. The observed augmentation in NHRR can be assigned to the introduction of hydrogen to the GGGBD20. The NHRR exhibited enhancement regardless of specific test fuel samples when the hydrogen quantity was increased. During the process of hydrogen addition, it is possible for the three stages of combustion to take place. During the initial stage, it has been observed that the combustion process of premixed biodiesel blend exhibits an earlier occurrence in comparison to that of hydrogen fuel. In the subsequent phase of our investigation, it has been noted that the utilisation of hydrogen as a fuel source leads to a notably higher degree of premixed combustion, as compared to the utilisation of GGGBD20. During the third stage, diffusion occurred in a comprehensive manner when GGGBD20 and hydrogen were combined. As a result, it is conceivable that the flame propagation may surpass the spray zone boundaries and infiltrate the hydrogen dispersed within the combustion chamber. The observed phenomenon that the laminar flame speed, potentially resulting in an increase of NHRR. Additionally, this effect is anticipated to cause an additional release of heat. Various researchers had obtained comparable findings [19].

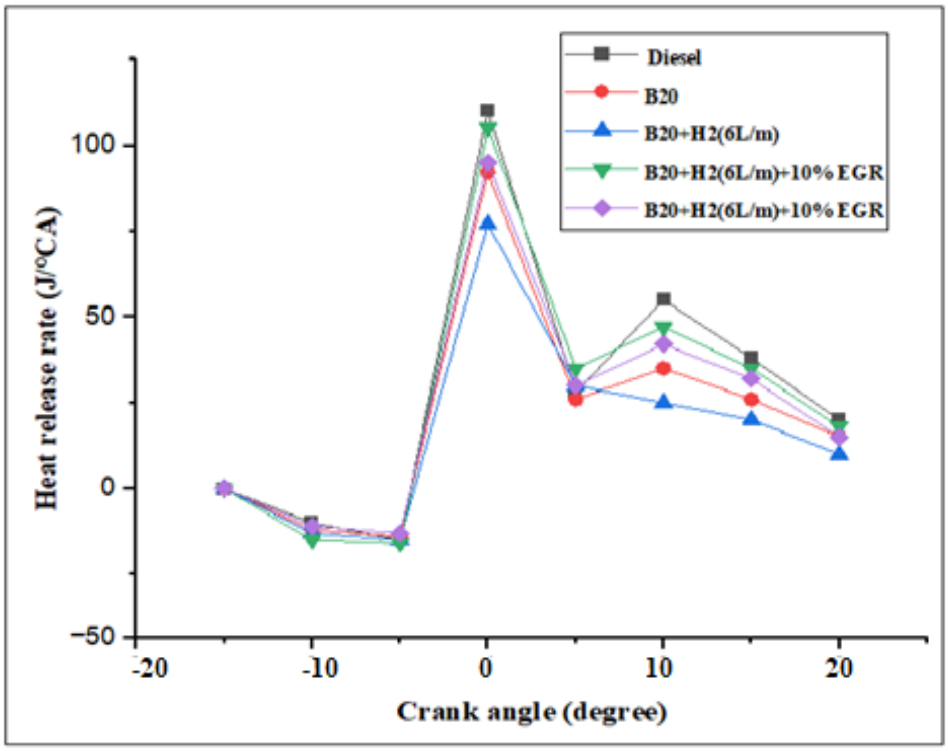


Figure 10. Heat release rate with crank angle.

Nomenclature

BP - Brake power
BTE - Brake thermal efficiency
CO - Carbon monoxide
CO_2 - Carbon dioxide
HC - Hydro carbon
HRR - Heat release rate
SFC - Specific fuel consumption

CONCLUSIONS

Increasing load increased test engine BTE when fuelled with GGGBD20. At all injection pressures, GGGBD20 has lower BTE than diesel. Increasing load lowered GGGBD20-fuelled test engine BSFC. At all loads, GGGBD20 has greater BSFC than diesel. A considerable reduction in CO, UHC, and smoke opacity for GGGBD20 was observed in comparison with diesel whereas the NO_x emission of GGGBD20 is more than diesel fuel. Except for NO_x, other emissions were lowered. It has been observed that BSFC, Peak CP, Peak NHRR, and NO_x emission of GGGBD20 biodiesel increased by 5.89%, 2.14%, 4.87%, and 30.47%, respectively.

On the other hand, BTE, CO, UHC, and Smoke Opacity of GGGBD20 biodiesel dropped by 3.56%, 3.86%, 46.13%, 30.16%, and 20.47% at full load than diesel fuel.

Conflicts of interest

The authors declare no financial or commercial conflicts of interest.

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