MULTIDISCIPLINARY SCIENCE JOURNAL

RESEARCHE ARTICLE
Published Online: November 14, 2023
https://doi.org/10.31893/multiscience.2024071

Effect on higher compression ratio on unmodified CI engine powered by biodiesel blend

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Abstract In order to keep up with the ever-increasing need for energy, the use of fossil fuels has no choice but to keep rising in tandem with the world's population, which is rapidly industrialising, urbanising, and expanding economically. Finding a suitable and environmentally friendly alternative to fossil fuels will become necessary if emissions from the use of fossil fuels continue unabated. Because of its renewable, non-toxic, and environmentally friendly character, biodiesel is an appropriate alternative solution that may be used in diesel engines. In the current investigation, the compression ratio of CI (Compression Ignition) engines was varied from 17 to 20 in an effort to find the optimum combination of performance, combustion, and emission characteristics for IC engines. When compared to the same blend at CR (Compression Ratio) 18, the BTE (Brake Thermal Efficiency) levels of KME20 (Kapok Methyl ester 20) at CR 19 were 5.6% higher. When compared to greater CR, the KME20 blend's emission values for both UBHC (Unburnt Hydro Carbons) and CO (Carbon monoxide) are higher than their respective values. When the compression ratio was reduced to 19, the emissions from the blend KME20 were 9.1% and 9.6% lower than when the same fuel was used at the standard compression ratio. It's possible that this is because the oxidation process of the hydrocarbons is more efficient, in addition to the fact that the temperature in the cylinder is high enough to promote full combustion.

Keywords: biodiesel, CI engine, compression ratio, combustion, emissions

1. Introduction

Biodiesel is considered a viable alternative to conventional diesel fuel, offering potential benefits in terms of sustainability and environmental impact mitigation (Saravanan et al., 2020). The substance possesses intrinsic lubricating properties and exhibits reduced emissions, therefore earning recognition as a fuel with environmentally sustainable combustion attributes (Selvam et al., 2023). Biodiesel or biofuel can be utilized without requiring any modifications in contemporary diesel engines, enabling direct usage in internal combustion engines. Biodiesel, or biofuel, represents the sole alternative energy source that offers a simplified utilization process (Nayyar et al., 2017). Biological fuels exhibit similarities to petroleum fuels, primarily in terms of their reduced emission characteristics. The fuel exhibits characteristics of renewability, biodegradability, and enhanced environmental safety. The augmentation of biodiesel production demonstrates economic advancement and mitigates the manufacture of pollutants. There are currently existing entities at both the national and domestic levels that engage in the manufacturing of biodiesel. Biodiesel exhibits compatibility with existing fuel compositions, allowing for its use in various proportions. Furthermore, it possesses the capability to function as a standalone fuel source within an internal combustion engine, devoid of the need for supplementary additives. In India, the production of plant-based biofuel encompasses several sources, such as Pongamia, Jatropha, Mahua, and several more. However, the commercialization of biodiesel in India has not yet been achieved (Nayyar et al., 2017). The present study examines the performance metrics and emission characteristics of engines with different compression values while altering the biodiesel blends in dual fuel mode. The oil was created by means of the transesterification process, wherein both rapeseed and Mahua oils were utilised in equal volumes (Krishnamoorthi & Malayalamurthi, 2018). The authors conducted experiments using a variable compression ratio (VCR) diesel engine, employing pure Mahua oil, pure rapeseed oil, a blend of the two oils in a 1:1 ratio, and a blend of the two oils with diesel fuel. The introduction of a 20% blend of biofuel resulted in improved performance as compared to diesel, with a decrease in Brake Thermal Efficiency (BTE) of 2.79%. However, at maximum load conditions, there is a decrease of 20.66% in carbon monoxide (CO) emissions, 8.56% in hydrocarbon (HC) emissions, and 6.9% in smoke emissions when compared to diesel fuel. These reductions are achieved without making any modifications to the engine, while there is only a slight increase in nitrogen oxide (NOx) emissions (Saravanan et al., 2020). In this study, an

Received: August 5, 2023 | Accepted: October 15, 2023

investigation was conducted to assess the performance of an n-butanol diesel blend on a CR diesel engine with reduced flexibility. The performance and emission characteristics were studied in this experiment by varying and examining the injection timing, pressure, compression ratio, and blend ratio. When the engine is operated with a mixture of 20% n-butanol and diesel fuel and a high compression ratio (CR) of 19.5, there is a noticeable enhancement in brake thermal efficiency (BTE) of 5.54%. Additionally, there is a significant reduction in smoke emissions by 59.56% and nitrogen oxide (NOx) emissions by 15.96% compared to when the engine is fuelled solely with diesel fuel. These improvements are observed at full load conditions. The study additionally posits that the utilisation of B20, a blend of gasoline, exhibits potential as an efficacious means of mitigating emissions while concurrently enhancing the performance of diesel engines (Krishnamoorthi & Malayalamurthi, 2018). The experiment was carried out utilising trans-esterified waste frying oil, which was blended with diesel fuel. The fuel mix was tested on a diesel engine featuring a single-cylinder configuration, along with other equipment such as a supercharger and other mechanisms to manipulate the air density and compression ratio. The experimental results demonstrate that the utilisation of a supercharger in dual-fuel mode leads to a significant enhancement of performance, specifically a 25% increase, while operating at a high compression ratio. Additionally, it is suggested that an increase in compression ratio resulted in the display of improved performance attributes. The present study provides a comprehensive analysis of the enhanced performance attributes exhibited by a single-cylinder diesel engine when operated with a blend of waste frying oil and diesel fuel. The study examined the impact of injection pressure and time on a VCR DI (Variable Compression Ratio in Direct Injection) diesel engine (Muralidharan et al., 2011). The researchers utilised mixes of bael oil, diethyl ether, and diesel fuel to assess the engine's performance and emission characteristics. In the present investigation, the fuel mixture denoted as B20, including 60% diesel, 30% bael oil, and 10% DEE, demonstrates a notable increase in brake thermal efficiency (BTE) by 3.5%. Additionally, this blend exhibits a reduction in hydrocarbon (HC) emissions by 7% and nitrogen oxide (NOx) emissions by 4.7% under full load conditions. These results were obtained at an injection pressure of 250 bar and an injection timing of 23°. Additionally, it is evident that the B20 blend exhibits superior performance and emission characteristics in comparison to alternative blends (Nagaraja et al., 2015). The study conducted by investigated the effects of different biofuel blends, derived from waste cooking oil, pyrolysis oil, and other sources, on the performance and emission characteristics of the CR Diesel engine. The study posits that transitioning to variable compression ratio (VCR) engines leads to improved performance attributes and decreased emissions of hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx) across all load conditions when using fuel mixes. Additionally, it is suggested that this technology enhances combustion efficiency, offers improved control during peak cylinder pressure, enables higher compression ratios, reduces fuel and power consumption, and decreases ignition delay across different load conditions. In conclusion, it has been determined that the utilisation of biodiesel at varying blend ratios, in conjunction with corresponding compression ratios, in a variable compression ratio (VCR) engine yields improved performance while simultaneously reducing engine emissions compared to a traditional engine. In this study, a series of experiments were performed on a VCRD engine using rice bran oil as the fuel. The oil was blended in five various compositions, ranging from 0% to 100%, with conventional hydrocarbon fuel. The emissions resulting from these blends were carefully measured and documented (Murugapoopathi & Vasudevan, 2019). The study highlights the significant improvement in emission characteristics observed in blends B10 and B20, which is attributed to a reduction in unburnt hydrocarbon and carbon monoxide emissions. The findings show that these blends could serve as a viable alternative to standard diesel fuel. It should be noted that an increase in the blending % is accompanied by a corresponding increase in the levels of NOx and CO_2 (Arumugam & Ponnusami, 2019). The study examined the performance, emissions, and combustion characteristics of a variable compression ratio (VCR) multifueled engine. The engine was fuelled with different mixes of trans-esterified methyl ester derived from wasted cooking oil. The compression ratios (CRs) were adjusted while maintaining a consistent speed and load. The researchers made the observation that the blend B40 exhibits a higher Brake Thermal Efficiency compared to clean diesel when operating at a compression ratio of 21 and a brake power of 2.02kW. However, the unburnt hydrocarbon exhibits an increase in ascent when subjected to higher compression ratios, accompanied by a minor elevation in nitrogen oxide levels. It should be noted that a lower compression ratio corresponds to a larger mean effective pressure, as shown by the designation B40. The researchers reached the conclusion that mixes falling within the lower and medium percentiles have the potential to serve as a viable alternative to diesel fuel. The engine was operated at varied compression ratios and various blends of warmed palm oil. Additionally, the study examined the impact of compression ratio on the engine's performance and emission characteristics. In the study, the researchers noted that while utilizing the PO20 blend, consisting of palm oil, under full load conditions, there was an observed increase in mechanical efficiency and brake power of around 14.6% and 6% respectively, in comparison to the performance of diesel fuel (Saravanamuthu et al., 2022). These findings were obtained at a compression ratio of 20:1. Although there is a decrease in HC and CO emissions when the blending percentage and compression ratios increase, the level of CO_2 emissions remains elevated. The exhaust gas temperature appears to be lower for all the blends compared to diesel (Sivalingam et al., 2022). It has also proved to be an alternate and possible fuel for conventional fossil fuels. Regarding this, the engine findings showed that compared to other fuels, the Kapok methyl ester 20%+ Diesel 80% (KME20) mix performs better and has better emission characteristics. Furthermore, it should be noted that the KME20 blend exhibits limitations such as reduced thermal efficiency and lower fuel economy. In order to address this concern, it is necessary to adjust the compression ratio for the compression-ignition (CI) engine. By using this approach, it is possible to achieve enhanced thermal efficiency and reduced emission levels in fuel utilization. In the current context, numerous prior studies have also demonstrated that altering the compression ratio yields improvements in performance attributes and reductions in emission levels. Based on a favorable consensus, the current study has opted to employ KME20 as a fuel source in the compression ignition (CI) engine. Because kapok seed, readily accessible in our locality, is a by-product of pillow manufacturing companies. Consequently, we have opted to utilize this waste seed as a valuable resource for the production of biodiesel. Specifically, we have employed the seed oil, methyl ester, derived from this seed, for the purpose of our current investigation with higher variable compression ratio. The engine characteristics results were evaluated and compared with the baseline Diesel operation.

2. Materials and Methods

2.1. Kapok oil Extraction Process

Kapok seeds' fiber sheath is harvested in Tamilnadu's southern areas, most specifically in the Theni region. The kapok seeds are removed from their woody shells and then dried outdoors in the sunlight until they change color and shrunk, making them ideal for use in the mechanical crusher. In order to extract the oil, the seeds are first mechanically crushed. After the completion of the extraction procedure, the waste products undergo filtration utilizing a suitable filter to accomplish the separation of the crude kapok oil (Baluchamy & Karuppusamy, 2021).

2.2. Process of Biodiesel Production

The trans esterification of kapok seed oil into methyl ester was carried out in a 1000 ml flask equipped with a condenser, temperature indicator, and a temperature-controlled water bath shaker. The procedure involved the utilization of 0.5 liters of straight kapok seed oil, 2.5 g of KOH as a reactant, and 200 ml of methyl alcohol (methanol). Before starting the reaction, the kapok seed oil was preheated on a heating plate to a temperature of 130°C. Following that, a mixture of catalyst and methyl alcohol was added to the reactor and stirred for 1.5 hours while maintaining a constant temperature of around 70°C. (Sakthi Rajan C, Muralidharan K 2021) Following that, the concoction was transferred to a separating funnel and allowed to remain undisturbed for a prolonged duration in order to promote the separation of the glycerol layer. The upper portion of the separating funnel, which contained the methyl ester layer, was then transferred to a different container once the glycerol in the lower portion of the separating funnel had sediment. The water present in the esterified cotton silk seed oil was removed by employing distilled water and blown air. Both the distilled water and blown air were subjected to distillation at around 120°C to eliminate any remaining traces of methanol and catalyst. Then, the Kapok seed oil methyl ester that had been made was allowed to cool (Baluchamy & Karuppusamy, 2021) (Figure 1and 2) (Table 1).

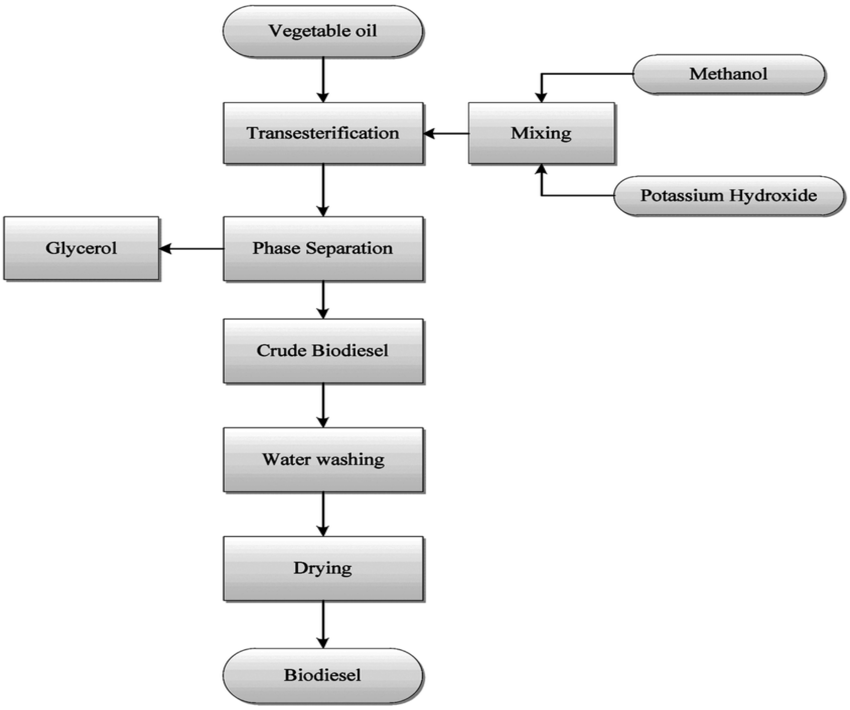

Figure 1 Process of Biodiesel Production.

Figure 2 Process of Biodiesel Production.

Table 1 Fuel properties for test fuel.

Properties Standard No.	Unit	Diesel ASTM D975	Biodiesel ASTM D6751	KME20	Diesel
Specific gravity(40°C)		0.85	0.88	0.866	0.830
Density (40 °C)	Kg/m³	0.834	0.84 - 0.90	866	830
Viscosity (40 °C)	mm²/s	4.10	1.50 - 6.00	2.85	2.3
Calorific Value	MJ/m³			41.85	44.50
Cetane Number		40-55	48-60	56	52
Acid Number	mgKOH/g	max 0.50	max 0.50	0.064	-
FFA	%		max 0.50	-	-
Fire point	(°C)	-	-	89	50
Flash Pont	(°C)	-	-	76	45

2.3. Experimental Setup

The engine chosen for the investigation is a single-cylinder, air-cooled, vertical direct injection, constant speed compression ignition (CI) engine, utilized for experimental purposes. The experimental configuration consisted of employing a multi-fuel engine with a variable compression ratio, which was coupled to an eddy current dynamometer. The application is employed for the evaluation of engine performance and combustion. The emission analyzer was installed for the purpose of evaluating emissions, collected the emission readings, whereas a computerized data collection system was utilized to obtain data from performance, combustion tests. The detailed engine layout was shown in figure 3, table 2 and 3.

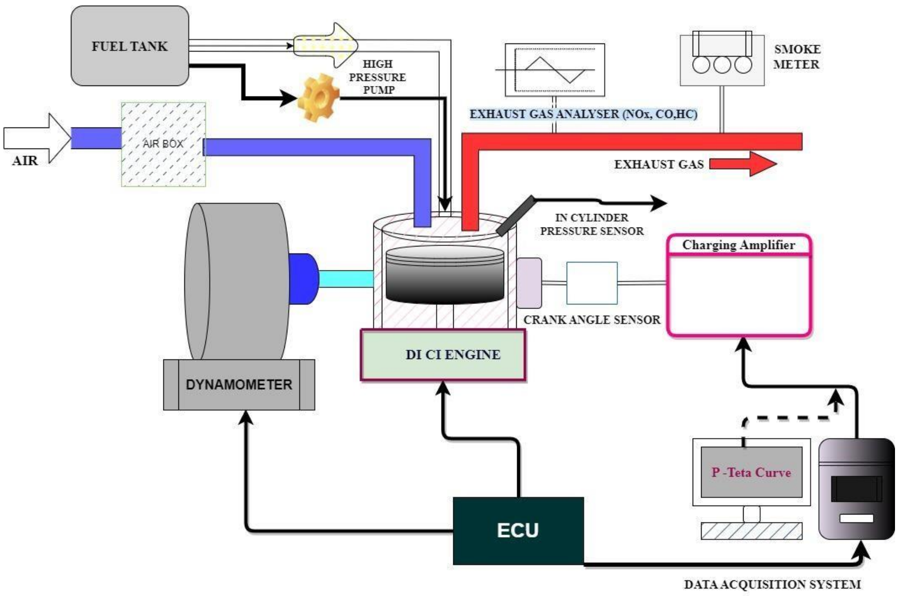

Figure 3 Experiment setup.

Table 2 Engine Specification.

Specification of Engine	
Brand and Model	Kirloskar, SV1
Number of cylinders	1
Cooling Types	Water-cooled
Stroke volume	661 cc
Engine speed	1800 rpm
No. of strokes	4
Clearance volume	37.8
Rated output	5.9 kW
Diameter of Bore	87.5 mm
Length of Stroke	110 mm
Lubrication system	Forced feed system
Compression Ratio	17-21

Table 3 Test description for various compression ratio conditions.

Fuel blends	Description
KME20 in CR17	KME20 in compression ratio 17:1
KME20 in CR18	KME20 in compression ratio 18:1
KME20 in CR19	KME20 in compression ratio 19:1
KME20 in CR20	KME20 in compression ratio 20:1

3. Results and Discussion

The experimental work was evaluated by decrement and increment of compression of the CI engine. The standard compression ratio of the test engine was 18:1, which varied from 17:1, 19:1 and 20:1, fuelled by a biodiesel blend. The test fuel was prepared to analyze its effect on the mono cylinder CI engine. The test condition was exposed in Table 4.

Table 4 Specification of Emission Analyzer.

Sl.No	Exhaust gas	Measuring range
1	UBHC	0-20,000 ppm Vol
2	CO	0-10% vol.
3	NOx	0-5000 ppm
4	O_2	0-22 vol %
5	CO_2	0-20% vol

3.1. Combustion Characteristics

3.1.1. Cylinder pressure

Figure 4 shows the evaluation of cylinder pressure for varying compression ratios fueled with KME20. It can be seen that the lower CR engine fueled with KME20 showed lower cylinder pressure for all load conditions. This is mainly due to reduced combustion rate and lower combustion temperature. The results exhibited that each time with an increment of compression ratio, the cylinder pressure also gradually raised. The noticeable reason was the high compression temperature of the air. At a lower compression ratio, air motion was significantly decreased, which led to poor air utilization that resulted in a lower combustion rate. At full load, peak cylinder pressure for CR 17, 18, 19 and 20 was 55.89 bar, 54.42 bar, 58.2 bar and 56.9 bar, respectively. It was noted that the brake power was increased from zero to peak condition, increment in-cylinder pressure for CR 17 is 58.4 %, for CR 18 is 64.7 %, for CR 19 is 68.5 % and for CR 20 is 65.45%, related to the standard value. It can be seen that the peak value of CR shows higher cylinder pressure than Diesel fuel. The KME20 with CR 19 exhibited 6.4%, 3.9% and 2.1% higher cylinder pressure than CR 17, 18 and 20 (Arumugam & Ponnusami, 2017).

3.1.2. Heat release rate

As seen in Figure 5, the HRR per degree of crank angle for varying the CR fueled with KME20. As seen, this research was conducted with the same fuel for all compression ratios. It was noted that the combustion efficiency was increased with an increase in the CR for the same fuel due to the rise in the heat release rate. There are four stages in the CI engine combustion process (Rajesh et al., 2023). These are ignition delay time, primary combustion phase, secondary combustion phase and after burning period. The peak HRR, i.e., the peak combustion, was noticeably less in low CR than higher CR. This is mainly due to the lower combustion efficiency and cylinder pressure compared to higher CR. For KME20 at CR 17, the HRR was 1.1%, 5.3% and 0.9% lower than other CR of 18, 19 and 20 because of the lengthened delay period, which leads to poor quantity of combustible fuel-air blend at the primary stage. The results of peak HRR for CR 17, 18, 19 and 20 were 62.52 J/^{o}CA, 62.8 J/^{o}CA, 65.67 J/^{o}CA and 63.01 J/^{o}CA, respectively. This is an evidence that CR 19 was observed to enhance the heat release rate compared to other CR. This is mainly due to better compression temperature, which reduces the delay period. Therefore, more fuel is burnt in the primary phase of combustion. With the same KME20 at CR 19, the HRR was improved by 5.2% as compared to Diesel at CR 18. This might be owing to a higher burning rate and better oxidation stability of hydrocarbon, which causes the complete combustion of fuel and increase in the HRR (Murugapoopathi & Vasudevan, 2021).

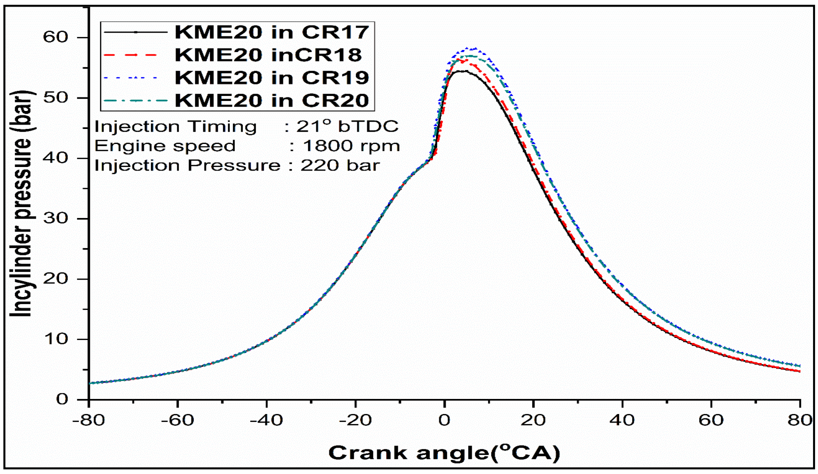

Figure 4 Variation of cylinder pressure with crank angle for different compression ratio.

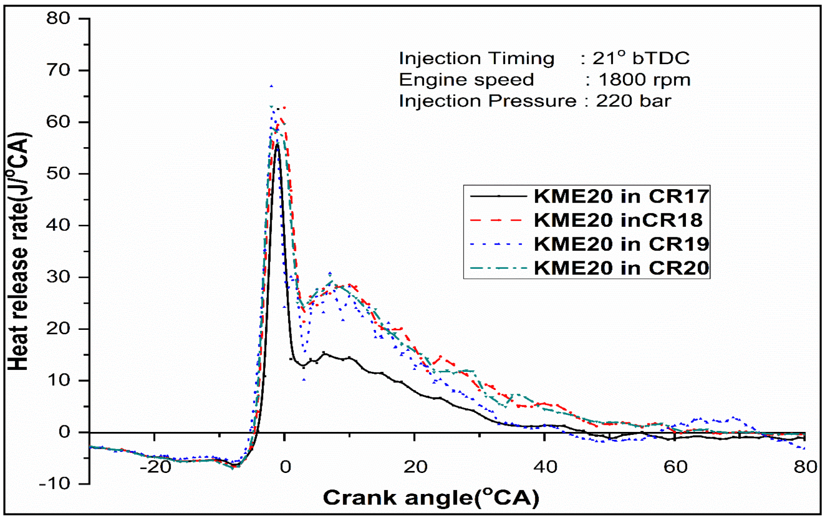

Figure 5 Variation of Heat Release Rate with crank angle for different compression ratio.

3.2. Performance Characteristics

3.2.1. Brake Thermal Efficiency

Figure 6 displays the comparison of thermal efficiency related to BP for fuel KME20 at different compression ratios. The result revealed that BTE decreased when the compression ratio was delayed. On the other side, increase in the compression ratio gradually increased the BTE for all load conditions. The maximum BTE for dissimilar CR for the KME20 blend is experiential at all of the capacity. At peak load, the result of BTE for CR 17, 18, 19 and 20 was 27.65%, 28.08%, 29.75% and 29.04%, respectively. The BTE of standard CR (18:1) was lower than the higher CR of the engine. Compared to standard CR, BTE of other CR 19 and 20 was increased by 5.6% and 3.3% for the same blend, KME20. It can be attributed to a higher compression ratio leading to high compression temperature, therefore, enhancing the oxidation process of hydrocarbon Due to the high compression temperature of the air, it can easily ignite the hydrocarbon, which reduces the combustion duration. Generally, the standard CR of the engine does not favor all test fuel. If the CI engine can be operated in smooth condition, it requires the compression temperature sufficient to self-ignite the fuel. Biodiesel has a higher self-ignition temperature than Diesel fuel which requires a high compression ratio to ignite the fuel (Sambandam et al., 2023). Hence, the present investigation increased the CR up to 20:1. From the figure, lower CR showed less performance than standard CR at full load conditions. For the KME20 blend at 17:1, the BTE was observed to be very low when compared to other CR. This might be owing to inferior mixing of the fuel-air inside the combustion chamber, which results in poor combustion. For the KME20 blend at 17:1, the result of BTE was decreased by 2.25% when associated with neat KME. This might be owing to the high viscosity of biodiesel, which affects the atomization and results in inferior combustion of the deprived fuel-air blend formation, thereby resulting in inferior combustion (Murugapoopathi et al., 2022).

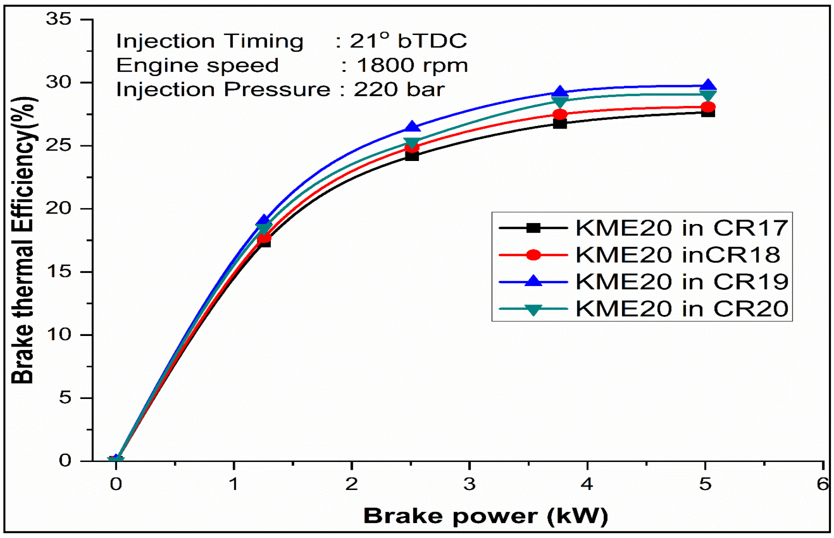

Figure 6 Variation of Heat Release Rate with crank angle for different compression ratio.

3.2.2. Brake specific energy consumption

Figure 7 exposes the variation of energy consumption rate related to BP for a different compression ratio of an engine fueled with KME20. KME20 blend showed better fuel economy than neat KME at high compression ratio conditions. It can be seen from the figure that as BSEC reduces the CR increases and the least BSEC was noticed for CR 20 at peak load conditions. It might be due to the decrease in viscosity of mixture, an increase in the CR takes place, therefore, allowing enhanced homogeneity of the mixer. It can be attributed to improving the oxidation process and energy economy characteristics. Thus, high CRs are favorable for better combustion rate and homogeneous mixture. Adopting high CR could improve the lean-burn operations. At rated speed, the result of BSEC for CR 17, 18, 19 and 20 was 13.01 MJ/kwh, 13.17 MJ/kwh, 12.39 MJ/kwh and 12.70 MJ/kwh, respectively. It is evident that the brake power was increased from zero load to full load, decrement in BSEC for CR 17 is 37.28 %, for CR 18 is 33.71%, for CR 19 is 36.32 % and for CR 20 is 38.5% related to zero value. As the CR was raised from 17 to 20, the percentage reduction in BSEC was 4.4 % for the same load and fuel condition. In addition, the engine fueled with KME10 at CR 19 showed a similar trend of energy consumption of Diesel fuel. Engine operation at CR 20 exhibited slightly higher fuel consumption than CR 19 at the same load due to a higher compression ratio, thereby leading to the promotion of unstable engine operation. High compression temperature and inherent O_2 in blend together showed better fuel economy. Finally, the results exhibited that the cost-effectiveness of fuel increases with the rise in CR (Ravikumar et al., 2021).

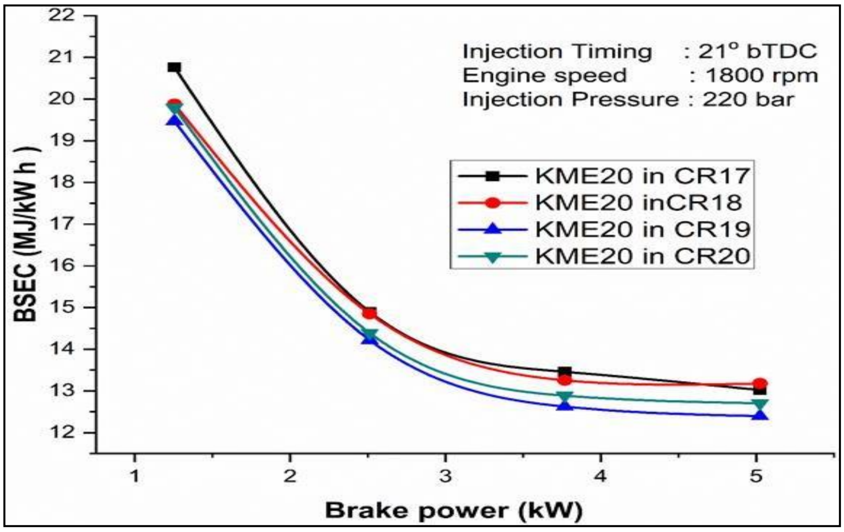

Figure 7 Variation of BSEC with Brake power for different compression ratio.

3.3. Emission Characteristics

Experimental work was conducted to find the values of exhaust emissions like HC, CO, smoke and NOx emission. The same were noted and reported for the four CRs with different load conditions.

3.3.1. Unburnt hydrocarbon

The HC emission is exposed in figure 8 for blend KME20 at various compression ratios with varying conditions of load. It was noted from the figure that HC decreases with increase of the compression ratio from 17 to 20. Even at a compression ratio of 20, the HC emission was slightly higher than CR 19 because of the unstable operation of the engine. The HC emission of CR 17, 18, 19 and 20 was 62 ppm, 61 ppm, 56 ppm and 58 ppm, respectively. It was evident that the compression ratio of 19 was 9.6% and 4.9% lower than other compression ratios of 17 and 18. This might be due to occurrence of complete combustion under these conditions. This is also attributed to sufficient air and higher gas temperature in the chamber (Ravikumar et al 2021). It was also over served that at a higher compression ratio of 19, HC emission was lowest at peak load conditions. It can be attributed to a higher compression ratio leading of elevated compression temperature, which enhances combustion rate. With various compression ratios from 17 to 20, the percentage of reduction in the HC value was 9.6% at the rated brake power condition. It was noted that as the load was increased from 0% to 75 %, the percentage of reduction in HC emission for CR 17 was 9.3 %, for CR 18 was 10.3 %, for CR 19 was 16.2 % and for CR 20 was 12.3%, of the initial value. An increase in combustion and homogeneous mixture formation is the reason for lower HC emission formation in higher compression ratio conditions (Padmanabhan et al., 2023).

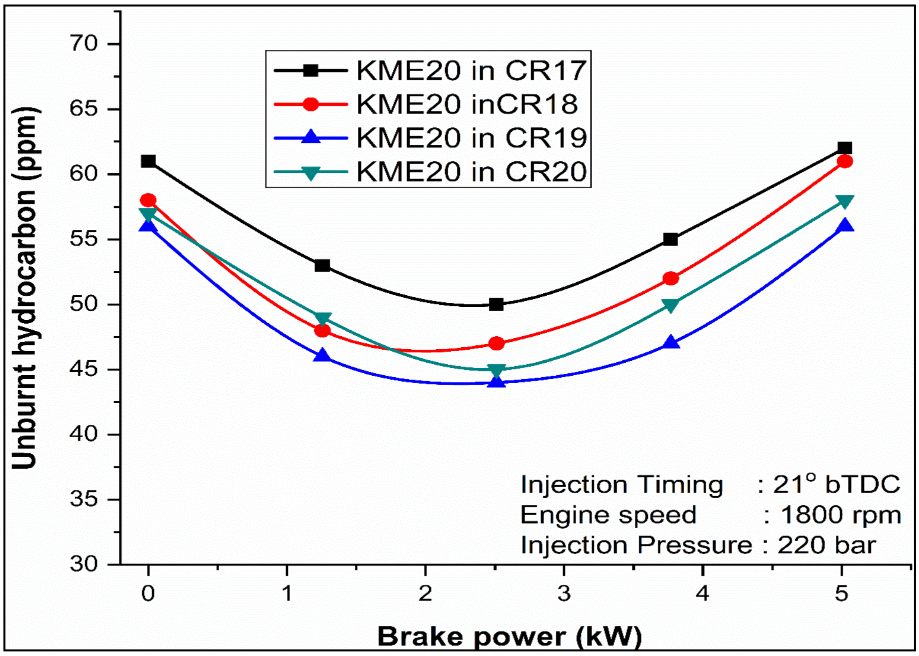

Figure 8 Variation of UBHC with Brake power for different compression ratio.

3.3.2. Carbon monoxide

The effect of various compression ratios on carbon monoxide formation in the CI engine is shown in figure 9. The CO value continuously decreases with an increase in the percentage of load for all compression ratios and load conditions. The obvious reason is that an increase in compression ratio leads to cylinder temperature, therefore, enhancing the complete combustion. The complete combustion of fuel, leads to leaving only a few traces of CO emission (Gaur et al., 2022). Both HC and CO are at higher compression ratios. It was evident that elevated air temperature and scattered air throughout the chamber enhanced the CO promotion. As the percentage of load can be varied from 0% to 90%, the value of CO was reduced by 22.5% for CR 17, for CR 18 is 20.6%, for CR 19 is 22.1% and for CR 20 is 21.6 %. In addition, the results of CO emission are reduced by 3.8% for KME20 at CR 17, for CR 18 is 6.9%, for CR 19 is 15.3%, and for CR 20 is 13.07%, as related to Diesel at CR 18:1. This might be due to inherent O_2 and an increase in the entropy of the mixture, which enhances CO_2 production. The result of CO emission for KME20 at CR 18 was 9.9% and 6.6% lower when compared to CR 19 and CR 20, respectively. It can be attributed to the suitable combustion at this compression ratio. For KME20 at CR 17, the capacity of CO emission was observed to be the highest because of the lower compression temperature and extremely rich mixture in the chamber, therefore, leading to lack of oxidation process.

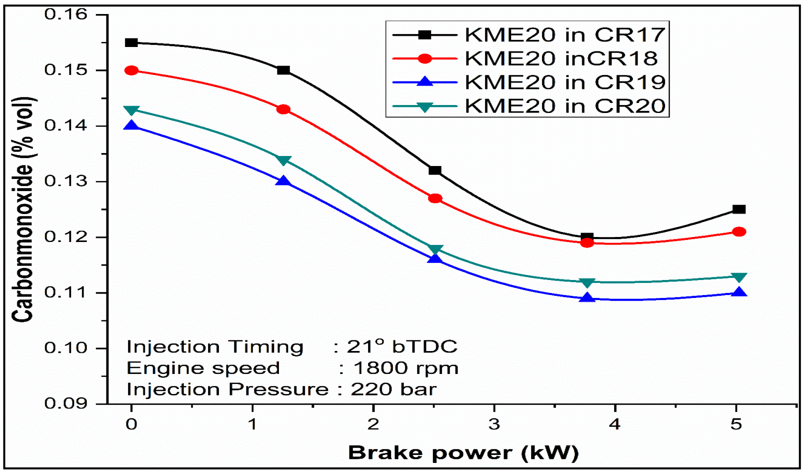

Figure 9 Variation of CO with Brake power for different compression ratio.

3.3.3. Nitrogen oxide

Figure 10 illustrates the assessment of NOx emission for varying the engine's compression fueled with KME20. The experimental results found that NOx emission increased with increase in CR. From the Supplementary Figure 10, it is evident that for all CRs except 17, the NOx emission increases between 744 ppm and 779 ppm for blend KME20. Under chemically correct mixture conditions, the NOx emission reaches the peak and decreased when the A/F charge becomes leaner or richer because of instantaneous combustion of charge. Moreover, when rising the load condition from zero to full load, the NOx emission gradually increases because of enhanced combustion temperature. As the cylinder temperature increased, the NOx formation increased because of favorable conditions for the nitrogen oxidation formation. At rated power, the result of NOx emission for CR 17, 18, 19 and 20 was 692 ppm, 744 ppm, 819 ppm, and 779 ppm, respectively. It is evident that the brake power was increased from zero to peak condition, increment in NOx emission for CR 17 is 82. 28 %, for CR 18 is 84.12%, for CR 19 is 88.25 % and for CR 20 is 85.23%, related to initial value. This might be due to an increase in cylinder temperature, which promote the chemical reaction of nitrogen and oxygen. For the KME20 blend at CR 19, the highest NOx emission is due to good atomization and flammability, which causes large quantities of NOx formation (Murugapoopathi et al., 2022).

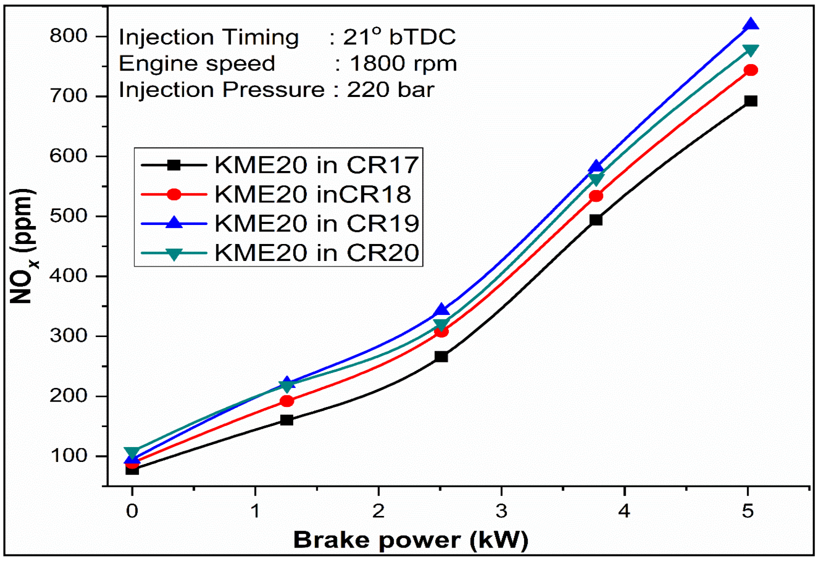

Figure 10 Variation of NOx with Brake power for different compression ratio.

3.3.4. Smoke

Figure 11 shows the analysis of smoke opacity in relation to brake power across various compression ratios for KME20. The findings of the investigation indicate that there was a 3.8% increase in smoke opacity for the KME20 blend at compression ratio (CR) 17, as compared to the KME20 blend at CR 18. In the context of KME20, it was observed that the blend at CR 18 exhibited a higher magnitude compared to blends with higher CR values. The smoke emissions observed a significant reduction when the compression ratio was set at 19 and 20. Nevertheless, the presence of a fuel-rich zone within the chamber had an impact on the smoke discharge. To achieve a greater compression ratio, one potential approach is increasing the air temperature, which can result in improved atomization of fuel droplets and therefore enhance the efficiency of combustion. The observed smoke emission concentrations for CRs of 17, 18, 19, and 20 were 52%, 50%, 48%, and 49%, respectively. The reason for the decreased smoke emissions associated with biodiesel is attributed to its lower carbon weight. The increase in smoke emissions for CR 17 is 79.8%, for CR 18 it is 81.29%, for CR 19 it is 79.25%, and for CR 20 it is 83.17%. The BP was raised from zero to peak. The primary reason for this phenomenon is that increased load circumstances necessitate a greater quantity of fuel to generate additional power, hence leading to the formation of a fuel-rich region within the combustion chamber (Gaur et al., 2022).

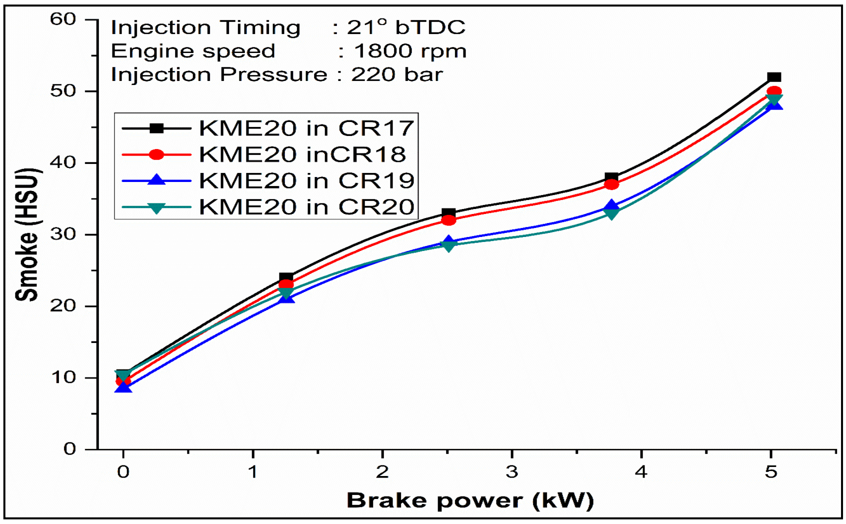

Figure 11 Variation of smoke with Brake power for different compression ratio.

4. Conclusions

On the combustion results, at full load, peak cylinder pressure for CR 19 was 58.2 bar dominated at higher CR but inferior at lower CR. HRR for CR19 with KME20 drastically improved HRR and CP at peak load conditions.

The KME20 at CR 19 showed higher BTE by 5.6% than the same blend at CR 18. KME20 at CR20 showed slightly lower BTE than CR 19 because too high compression temperature leads to irregular combustion duration and the possibility of knocking.

CR 19 with KME20 drastically reduced fuel consumption due to better combustion efficiency. As the CR was raised from 17 to 20, the percentage reduction in BSEC was 4.4 % for the same load and fuel condition.

For lower CR, the emission values of HC and CO are higher as compared to higher CR with the KME20 blend. The blend KME20 at CR 19 exhibited 9.1% and 9.6% lower HC and CO emissions than the same fuel at standard compression ratio.

This might be due to a better oxidation process of hydrocarbon and sufficient temperature in the cylinder, which promote complete combustion.

The smoke emission of KME20 at CR 19 was 10.65% and 3.5% lower for Diesel and KME20 at CR19.

The effect of varying compression ratios with KME20 leads to enhanced compression temperature and air utilization, thereby, resulting in complete combustion.

On the whole, it was concluded that KME20 at CR 19 noticed an enhancement of the performance and combustion characteristics compared to the standard compression ratio.

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

Funding

This work is not funded by any agency.

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