Research Article

Assessment of Kusum Biodiesel and Octanol Blends on Diesel Engine Performance and Emissions: A Comprehensive Study of Efficiency Trade-offs and Environmental Benefits

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Abstract This paper aims to investigate the effect of Kusum biodiesel and Octanol blends on Kirloaskar TV1 single cylinder diesel engine in terms of performance and emission. The tested blends, KB10O10D80, KB20O10D70, KB30O10D60, and KB40O10D50, revealed a significant decrease in emissions such as CO, HC, and smoke with an increase in biodiesel content at different engine loads. In particular, the KB10O10D80 blend, which had the lowest biodiesel content, recorded a CO reduction of 2.8% to 14.7%, HC reduction of 17.9% to 21.1% and smoke reduction of 3.45% to 18.18%, compared to diesel. However, the highest blend, KB40O10D50, recorded the highest emissions decrease with a reduction of CO by 27%, and a reduction of HC by 65.8% reduction in HC, and a 72.73% reduction in smoke at lower engine loads. But the study also found that brake thermal efficiency (BTE) reduced and brake specific energy consumption (BSEC) increased with the increase in biodiesel content. KB10O10D80 had the least reduction in BTE with the maximum reduction being 19.78% at 75% load and a moderate increase in BSEC, with an 11.66% increase at 100% load. However, the efficiency loss was the highest in KB40O10D50, but the emissions were reduced to the highest extent. Additionally, NOx emissions increased slightly, with KB10O10D80 showing a rise of 0.1% to 1.81%, and KB40O10D50 recording up to a 5.36% increase at full load. These findings underscore the trade-offs between environmental benefits and engine performance. The presence of Octanol, an oxygenated additive, improved combustion efficiency. However, the KB20O10D70 produced better performance and notably reduced emission.

Keywords: Diesel engine, Emissions, Kusum seed, n-Octanol, Performance.

I. INTRODUCTION

Depletion of renewable resources is an increasingly pressing issue, as the continuous extraction and consumption of natural resources, even those considered renewable, are reaching unsustainable levels. Biomass, wind, and solar energy are supposed to be replenished in a short time and are therefore categorized as renewable resources. But if used and managed inappropriately, they can be depleted, and this will cause long-term environmental and economic problems. One such alternative is biodiesel produced from non-edible waste materials such as seeds of trees like Kusum, scientifically known as Schleichera oleosa [1]. The Kusum seeds are usually thrown away as waste but the oil which is found in them can be used to produce biodiesel. Using such waste resources not only solves the problem of the exhaustion of traditional renewable resources, but also realizes the concept of circular economy, where waste materials are used to generate energy[2]. Through biodiesel from Kusum seed oil, the world can now turn to a renewable resource that is environmentally friendly and also at the same time deal with the issue of waste disposal. Schleichera oleosa is a prominent species in the Sapindaceae family and has multiple uses in medicine, agriculture, and industries. The Kusum tree is native to the tropical regions and is mostly located in India where it is an important source of income for the rural people. It is a deciduous or semi-evergreen tree, which is used ethnobotanically and as a host tree for lac culture [3]. The tree bears small, fleshy fruits known as berries that are either one or two- seeded. The Kusum tree is mainly located in India, but it is also present in other tropical countries, although the exact data on the distribution of the tree around the world are scarce. It is particularly common in Orissa and in the Darjeeling Himalayas, Andhra Pradhesh and Tamil Nadu where it is grown as a home garden tree. The climatic factors like rainfall and temperature affect the germination of seeds and growth of the tree which is important for its reproduction and spread. However, there is need to be addressed in terms of waste and harmful components. The waste produced from Kusum processing like most other agricultural and industrial processes if not well disposed can cause a lot of harm to the environment and the health of the people[4]. This response looks at the negative attributes of Kusum waste, possible environmental impacts and how these impacts can be prevented. Like other agricultural residues, Kusum waste may contain heavy metals including lead, cadmium, nickel, zinc and copper. These elements when present in high concentrations are a threat to the ecology and human health. For instance, in Akure, Nigeria, the study showed that the soils and sediments contained these metals and this poses a threat to human health and the environment [5]. Heavy metals in wastes can cause cytotoxic and genotoxic impacts on plants and animals. Research has revealed that metals such as Cu, Zn, and Pb can lead to chromosomal aberrations and other genetic changes in plants, which in turn affects the whole ecosystem. Disposal of Kusum waste in the wrong manner poses a threat to the soil and water resources. The accumulation of heavy metals and other pollutants in the soil can affect plant growth and enter the food chain, posing risks to human and animal health. Another strategy of handling hazardous waste is fractionation that involves sorting the waste into solid and liquid fractions. The solid part containing heavy metals can be safely disposed off while the liquid part can be utilized as fuel thus reducing on the conventional fuel usage and air borne emissions[6]. The investigations show that Kusum biodiesel can improve the engine efficiency and decrease some emissions but at the same time, it can raise NOx emissions. In general, the blends of Kusum biodiesel have been observed to have an enhanced BTE up to a certain blend ratio. For example, the biodiesel/diesel mixture of 20% Kusum biodiesel with 80% diesel (K-20 D-80) was found to be the best one as it increases BTE than that of diesel [7]. In the same way, the blending of hydrogen-compressed natural gas (HCNG) to KSOBD20 also enhanced the BTE to its maximum of 32. 09% at an injection pressure of 240 bar [8]. The study on the performance of n-Octanol as an additive in diesel engines has been investigated with the aim of improving the performance and reducing emissions, thus making it one of the best alternative fuel components. The study shows that n-Octanol has the potential of enhancing the efficiency of engines and lowering the emission of toxic gases but at the same time, it has some drawbacks that should be considered. This response will discuss the impact of n-Octanol on the diesel engine performance, emission and combustion using the findings from the above studies. Brake Thermal Efficiency (BTE): Literature surveys reveal that n-Octanol blends enhance brake thermal efficiency in a manner that is unchanging across experiments. This improvement is attributed to the fact that n-Octanol has more oxygen available for combustion as compared to heptane[9]. Nevertheless, due to the lower energy content of n-Octanol as compared to diesel, there is an increase in brake-specific fuel consumption [10]. Power Output: The presence of n-Octanol can result to a longer ignition delay because of its high latent heat of vaporization that decreases the initial combustion temperature and increases power [11].

The n-Octanol blends have been observed to decrease CO, HC and smoke opacity emissions by a large margin. This is mainly because n-Octanol is an oxygenated compound and thus, it undergoes complete combustion as compared to n-heptane [12]. Nitrogen Oxides (NOx) Emissions: In general, n-Octanol blends decrease NOx emissions compared with pure diesel, but increasing the proportion of n-Octanol in the blend increases the relative emissions of NOx. This is because of the formation of fuel rich zones that can raise local temperatures and formation of NOx [13]. Soot Formation and Oxidation: The presence of n-Octanol in biodiesel blends influences soot formation and oxidation phenomena. Even though the inception and coagulation rates are higher at higher n-Octanol to fuel ratios, the soot mass is lower because of higher oxidation [14]. Combustion Stability: n-Octanol has solubilising properties and helps in improving ignition qualities of fuel blends and increases stability of the blends. This is especially so in the blends with other alcohols or biodiesel where phase separation and low cetane numbers may be a problem [15]. In the light of the above findings, it can be concluded that n-Octanol has the potential of being used as a biodiesel additive; however, this comes with some trade-offs. The increase in BSFC due to the lower energy content of n-octanol may reduce some of the efficiency improvement. Furthermore, it is also found that the NOx emissions may rise with the increase in n-Octanol concentration and therefore, the blend ratios should be optimized to get the best balance of performance enhancement and reduced emissions [16]. In addition, the addition of n-Octanol to other additives like diethyl ether or nanoparticles is also known to improve combustion and emission characteristics, which mean that a multiple component system is desirable [17].

The Kusum biodiesel blends are seen to decrease the BSFC, which means better fuel economy. The KSOBD20 blend with HCNG recorded a BSFC of 0. 227 kg/kWh, which is less than that of diesel [18]. The B10 blend also had lower BSFC at full engine load conditions as shown in the study made by [19]. In general, the CO and HC emissions of Kusum biodiesel blends are lower than that of diesel. The KSOBD20 blend with HCNG reduced the CO and HC emissions to a large extent with the CO emission level reducing to 0. This was done by reducing the emission of CO to 013%, HC to 47 ppm [20]. One of the findings that is evident in most of the research is the rise in NOx emissions when using kusum biodiesel blends. This is due to the fact that biodiesel has higher oxygen content that leads to complete combustion and higher combustion temperature [21]. Kusum biodiesel blends are likely to decrease smoke and particulate emissions. The KSOBD20 with HCNG lowered the smoke emissions to 9% [22]. Likewise, the smoke density of the B10 blend was found to decrease as the proportion of biodiesel was raised [23]. The incorporation of hydrogen into the blends of kusum biodiesel has the effect of improving combustion features. The KSOBD20 blend with 15 lpm hydrogen got the CP of 69. 34 bar and an NHRR of 66.04 J/deg, which is an enhancement in the combustion efficiency [24]. It has been found that the best biodiesel blend is 20% Kusum biodiesel and 80% diesel because it has the best balance of performance and emissions [25]. Other sophisticated modeling approaches such as ANFIS-GA have been applied in estimating the performance of the engine and emissions, and in determining the right blending ratios [26].

II. NOVELTY STATMENT

While kusum biodiesel shows promise as an alternative fuel, challenges such as increased NOx emissions and the need for optimal blending ratios must be addressed. The use of higher alcohol additives like n-Octanol can enhance performance and reduce emissions, making kusum biodiesel a viable option for sustainable energy solutions. However, there is a lack of research n-Octanol blend with kusum biodiesel draws further attention towards this research where the engine performance were evaluated for KBOD blend

III. MATERIALS METHOD

Kusum seeds are first collected and cleaned to remove dust, debris, and other impurities. The cleaned seeds are then subjected to mechanical pressing, where they are crushed using a mechanical press to raw oil. Mechanical pressing is a physical process that does not involve chemical solvents, making it a cleaner extraction method. The resulting crude Kusum seed oil may contain impurities, free fatty acids (FFA), and other residues, making it necessary to refine or treat the oil before using it in the biodiesel production process. The crude oil is then washed to remove solid particles and sediments from the crude oil to produce cleaner oil for the next reactions.

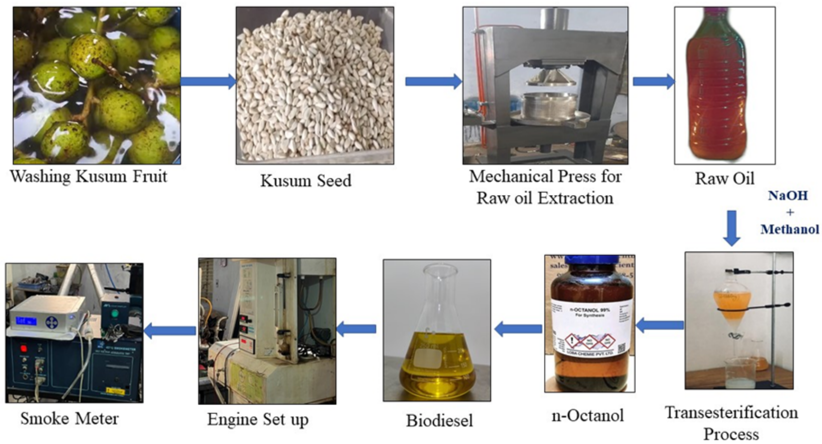

Figure 1: Schematic representation of process flow

The raw oil obtained from the mechanical pressing contained phospholipids, free fatty acids and water which will influence the efficiency of the transesterification process. The first process in pre-treatment is degumming where phospholipids and other impurities are separated and this is achieved through water treatment. The Kusum seed oil which has been pre-treated undergoes a chemical process known as transesterification to produce biodiesel. The oil is then blended with methanol and a catalyst sodium hydroxide (NaOH). The reaction occurs at the range of 60 to 65 °C, which is effective for the blending of the oil and methanol. The ratio of alcohol to the Kusum raw oil is normally 6:1 in order to achieve a stoichiometric reaction. The catalyst is soluble in alcohol and this is followed by the addition of this mixture to the oil. The reaction breaks down the triglycerides in the oil, forming methyl esters (biodiesel) and glycerol as a by-product. Once the transesterification reaction is complete, the reaction mixture is allowed to settle into two distinct layers. The upper layer consists of biodiesel (fatty acid methyl esters), while the lower layer contains glycerol, which is the by-product of the reaction. The separation happened by gravity based. The biodiesel is carefully decanted from the glycerol, which can be purified further. The glycerol layer may also contain traces of unreacted methanol, catalysts, and other impurities, which need to be removed before further use.

Table 1: Fuel composition and its nomenclature

Nomenclature	Kusum Biodiesel (KB)	n-Octanol (O)	Diesel (D)
KB10O10D80	10% by vol.	10% by vol.	80% by vol.
KB20O10D70	20% by vol.	10% by vol.	70% by vol.
KB30O10D60	30% by vol.	10% by vol.	60% by vol.
KB40O10D50	40% by vol.	10% by vol.	50% by vol.

The crude biodiesel obtained from the transesterification process still contains residual catalysts, methanol, soap, and glycerol that must be removed before the biodiesel is suitable for use. The purification process involved washing the biodiesel with warm water to dissolve and remove these impurities. The washing process can be done several times until the water comes out clear, ensuring that the biodiesel is free from contaminants. After washing, the biodiesel must be dried to eliminate any residual water. The overall process flow were depicted in the figure 1. After completing the transesterification, separation, and purification processes, the final product is ready for use. This Kusum biodiesel were blended with regular diesel and n-Octanol in different proportions as provide in the Table 1.

The theoretical yield of biodiesel was calculated based on the stoichiometry of the transesterification reaction, where one mole of triglyceride reacts with three moles of methanol to produce three moles of methyl esters (biodiesel) and one mole of glycerol. Assuming an average molar mass of Kusum oil triglycerides of approximately 885 g/mol, 2 liters of oil (1.84 kg, assuming a density of 0.92 g/mL) equated to about 2.08 moles of triglycerides. Using a 6:1 molar ratio, 6.24 moles of methanol were required, which corresponds to approximately 199.68 g of methanol (250 mL based on density). The theoretical mass of biodiesel was calculated as 1,823 g (or about 1.82 liters, assuming a density of 0.9 g/mL). The actual biodiesel yield was 1.7 liters, resulting in a yield percentage of 93.4% ((1.7 / 1.82) × 100). This high yield indicates efficient conversion, attributed to optimal reaction conditions, including accurate control of temperature, methanol ratio, and effective phase separation. The slight discrepancy between theoretical and actual yields is likely due to minor losses during washing and separation stages, demonstrating the effectiveness of Kusum oil as a viable feedstock for biodiesel production with high conversion efficiency. n-Octanol is obtained from the lobo chemie private limited, with 99% of purity. Purchased n-Octanol was added directly with the transesterified diesel to improve the fuel property at kept stirred with magnetic stirrer for 5minutes for homogeneous mixture. However, the n-Octanol content was limited to 100ml per litre for the various blends. The blends and its fuel composition are shown in the table 1.

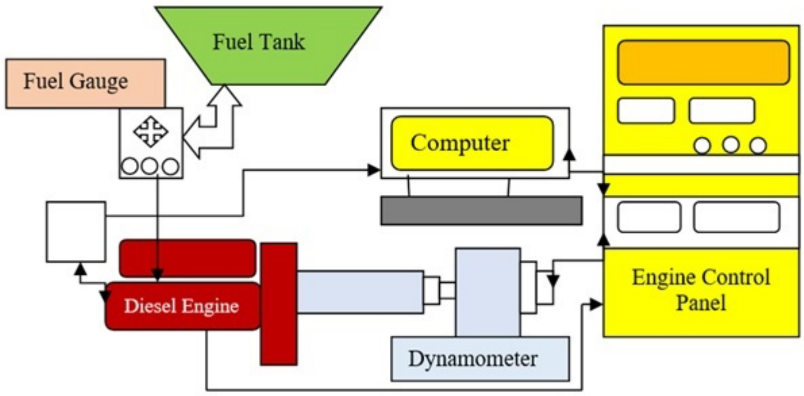

Figure 2: Experimental Setup

The experimental setup is shown in figure 2. In this study a single cylinder water-cooled Kirloskar TV1 engine was used with an engine capacity of 660cc and the fuel was injected at 21 bTDC and injection pressure at 210 bar with rated output of 5.2kW at 1500rpm. The inlet temperature was maintained at room temperature. Depending on the configuration, the load can range from zero to 5.5 kilowatts. The engine generates 5.5 kilowatts of power at a load of 0%, 25%, 50% and 100%. Diesel and biodiesel can be mixed with air in the fuel container, and the fuel mixture ratio can be adjusted using the fuel analyzer on the control screen. The AVL five-gas analyzer is used to measure gases emissions such as CO, CO_2, HC, O_2, and NO, while an AVL-developed smoke measuring instrument is used to assess the level of exhaust smoke.

IV. RESULT AND DISCUSSION

The engine was kept 15 minutes idle before each blend fuel operation. The engine kept to run till 15 minutes after attaining equilibrium, after final readings were taken and observed data were interpreted in this section.

4.1 Brake Thermal Efficiency

The brake thermal efficiency (BTE) of the Kusum biodiesel and Octanol blends (KB10O1D80, KB20O1D70, KB30O1D60, KB40O1D50) was compared with pure diesel across different engine loads at represented in the figure 3. At 0% load, BTE for diesel was 4.97%, while KB10O1D80 showed a slight decrease of 3.22%, and KB40O1D50 had a significant reduction of 17.46%. As the engine load increased to 25%, diesel had 19.1% BTE, with KB10O1D80 exhibiting a minimal drop of 3.09% and KB40O1D50 dropping by 18.32%. At 50% load, BTE for diesel was 25.7%, and KB10O10D80 experienced a moderate 3.11% decrease, while KB40O10D50 saw a more notable 17.87% reduction. Similarly, at 75% load, diesel reached 27.8%, with KB10O10D80 closely trailing at a 2.52% reduction, but KB40O10D50 lagging with a 19.78% decrease. At 100% load, diesel achieved 31.73%, whereas KB10O10D80 dropped by 2.24%, and KB40O10D50 significantly declined by 14.57%. Overall, KB10O10D80, containing 10% Kusum biodiesel and 10% Octanol, consistently performed closest to diesel across all loads, showing the smallest efficiency decrease, while KB40O10D50, with the highest Kusum biodiesel content (40%), had the greatest reduction in BTE. The lower BTE values with increased Kusum biodiesel content can be attributed to its lower calorific value compared to conventional diesel. Kusum biodiesel's reduced energy content per unit volume results in lower thermal efficiency, particularly at higher engine loads where more energy is demanded. The addition of Octanol, a higher oxygenated compound, helps improve the combustion process by providing more oxygen during combustion, enhancing fuel burn efficiency. However, the effect of Octanol is not enough to counterbalance the lower energy density of the higher Kusum biodiesel blends. This is evident in KB40O10D50, where a significant reduction in BTE is observed despite the presence of Octanol. On the other hand, KB10O10D80 maintains relatively higher thermal efficiency due to its higher diesel content, which helps sustain combustion performance. Overall, while Kusum biodiesel contributes to the sustainability of the blend, its increasing proportion leads to diminishing BTE, with Octanol serving to mitigate but not eliminate the efficiency losses.

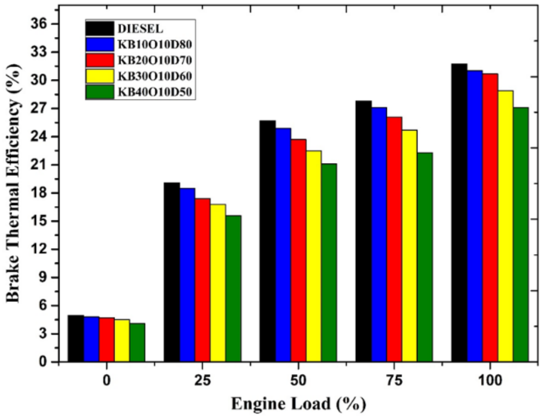

Figure 3: Brake thermal efficiency of KBOD blends at varied engine load

4.2 Brake specific Fuel Consumption

The Brake Specific Energy Consumption (BSEC) values for DIESEL, KB10O10D80, KB20O10D70, KB30O10D60, and KB40O10D50 show distinct variations across engine loads were depicted in the figure 4. At 0% load, DIESEL had a BSEC of 20342 kJ/kWh, while KB10O10D80 increased by 2.31%, and KB40O10D50 saw a 5.56% rise. At 25% load, DIESEL's BSEC was 162O10 kJ/kWh, with KB10O10D80 rising by 1.54%, and KB40O10D50 showing a 7.54% increase. For 50% load, DIESEL had 13200 kJ/kWh, and KB10O10D80 recorded a 6.44% increase, while KB40O10D50 rose by 8.97%. At 75% load, DIESEL reached 106O10 kJ/kWh, with KB10O10D80 increasing by 3.75%, and KB40O10D50 up by 11.75%. Lastly, at 100% load, DIESEL stood at 9841 kJ/kWh, while KB10O10D80 rose by 3.87%, and KB40O10D50 showed an 11.66% increase. Overall, the BSEC increases progressively with higher Kusum biodiesel content in all load conditions.

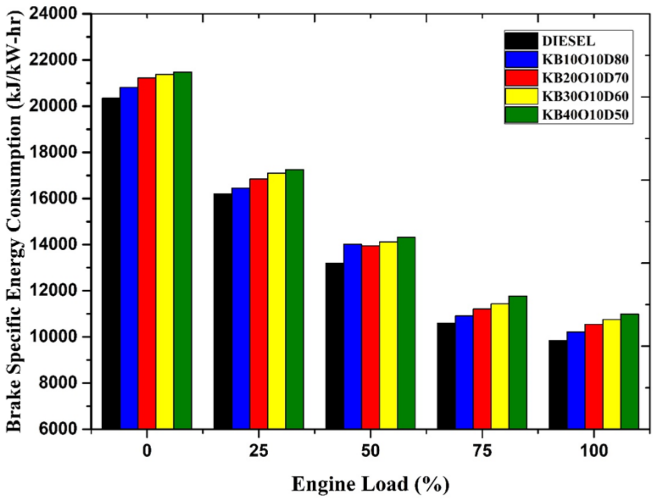

Figure 4: BSEC of KBOD blends at varied engine load

The rise in BSEC values with increasing Kusum biodiesel content is primarily due to the lower calorific value of biodiesel compared to conventional diesel. As more Kusum biodiesel is blended, more energy is required to produce the same amount of brake power, leading to a higher BSEC. Furthermore, the oxygenated nature of n-Octanol improves combustion efficiency, but it cannot fully offset the reduced energy density of Kusum biodiesel, particularly at higher blending ratios like KB40O10D50. This explains the progressively higher BSEC values observed with increasing biodiesel content. While lower blends like KB10O10D80 show relatively minor increases, higher blends such as KB40O10D50 exhibit more pronounced energy consumption increases, especially at higher loads, due to the significant difference in fuel properties from pure diesel.

4.3 Oxides of Nitrogen

The NOx emissions for DIESEL, KB10O10D80, KB20O10D70, KB30O10D60, and KB40O10D50 show changes across different engine loads were depicted in the figure 5. At 0% load, DIESEL recorded 999 ppm, while KB10O10D80 showed a slight increase of 0.1%, and KB40O10D50 exhibited a 2.1% rise. At 25% load, DIESEL emitted 1035 ppm, with KB10O10D80 showing a 0.58% increase, and KB40O10D50 rising by 3.57%. At 50% load, DIESEL emitted 1358 ppm, with KB10O10D80 increasing by 0.96%, and KB40O10D50 rising by 3.09%. At 75% load, DIESEL reached 1430 ppm, with KB10O10D80 showing a 1.33% increase, and KB40O10D50 rising by 4.96%.

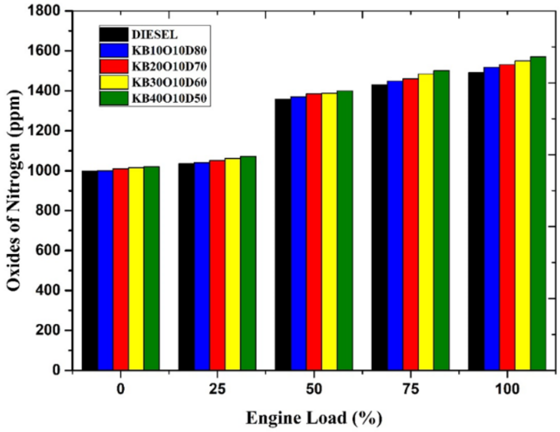

Figure 5: NOx emission of KBOD blends at varied engine load

At 100% load, DIESEL emitted 1491 ppm, with KB10O10D80 increasing by 1.81%, and KB40O10D50 showing a 5.36% rise. In general, NOx emissions show a progressive increase with higher Kusum biodiesel content across all engine load conditions. The increase in NOx emissions with higher blends of Kusum biodiesel can be attributed to the oxygenated nature of both biodiesel and n-Octanol, which enhance combustion efficiency and raise in-cylinder combustion temperatures. Elevated temperatures lead to higher thermal NOx formation, especially at higher engine loads where combustion intensity is greater. This is most evident in KB40O10D50, where the higher biodiesel proportion results in a significant rise in NOx emissions compared to diesel. The additional oxygen content promotes better fuel-air mixing, improving combustion but also raising peak temperatures, thereby increasing NOx formation. Although the presence of n-Octanol helps maintain combustion efficiency, it also contributes to the temperature rise, exacerbating NOx emissions in higher biodiesel blends. Therefore, while biodiesel blends improve the combustion process, the higher oxygen content and increased combustion temperatures explain the observed increase in NOx levels.

4.4 Smoke

The smoke emissions for DIESEL, KB10O10D80, KB20O10D70, KB30O10D60, and KB40O10D50 show significant variations across different engine loads were depicted in the figure 6. At 0% load, DIESEL recorded 11%, with KB10O10D80 showing a 18.18% decrease, and KB40O10D50 exhibiting a 72.73% reduction. At 25% load, DIESEL had 19%, with KB10O10D80 decreasing by 10.53%, and KB40O10D50 showing a 47.37% reduction. For 50% load, DIESEL emitted 29%, while KB10O10D80 saw a 3.45% decrease, and KB40O10D50 showed a 27.59% reduction. At 75% load, DIESEL had 41%, with KB10O10D80 recording a 7.32% decrease, and KB40O10D50 showing a 26.83% reduction. Lastly, at 100% load, DIESEL reached 59%, while KB10O10D80 decreased by 8.47%, and KB40O10D50 showed a 33.90% reduction. In summary, smoke emissions decrease progressively with higher Kusum biodiesel content across all engine loads, with the most significant reductions occurring in higher blends such as KB40O10D50.

The reduction in smoke emissions with increasing Kusum biodiesel content is primarily due to the oxygenated nature of both biodiesel and n-Octanol. These oxygenated compounds improve combustion by providing more oxygen during the fuel burn, leading to a more complete combustion process and significantly lowering particulate formation, which is the primary contributor to smoke. The oxygen content in biodiesel promotes a better fuel-air mixture, leading to reduced soot formation, especially at higher loads where diesel engines typically produce more smoke due to incomplete combustion. In higher blends like KB40O10D50, the reduced soot emissions are more pronounced, reflecting the increased oxygen availability from the biodiesel and Octanol mixture.

This results in lower particulate matter and reduced smoke formation compared to diesel, particularly at higher engine loads where combustion processes become more intense. Therefore, while the use of Kusum biodiesel in combination with n-Octanol helps improve combustion efficiency, it also significantly lowers smoke emissions across all engine load conditions.

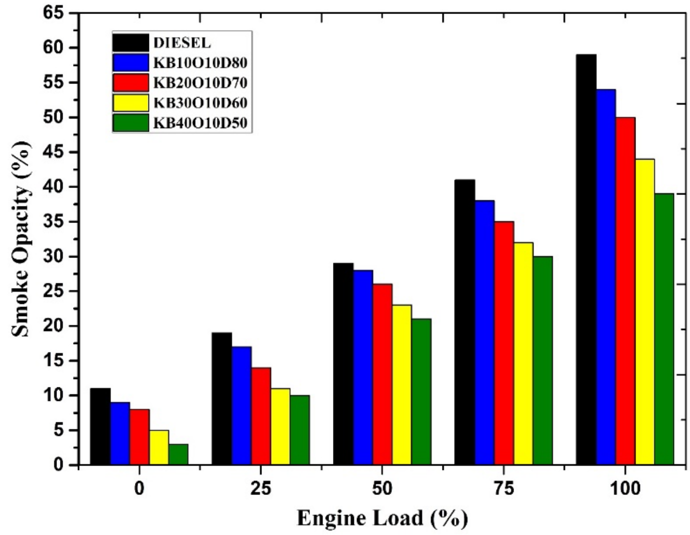

Figure 6: Smoke opacity of KBOD blends at varied engine load

4.5 Hydrocarbon emission

Comparing the hydrocarbon emissions of various blends (KB10O10D80, KB20O10D70, KB30O10D60, and KB40O10D50) to pure diesel reveals significant reductions at each engine load level were depicted in the figure 7. At 0% engine load, KB10O10D80 shows a 21.1% decrease in emissions compared to diesel, KB20O10D70 shows a 36.8% decrease, KB30O10D60 shows a 44.7% decrease, and KB40O10D50 shows a 65.8% decrease. At 25% engine load, emissions decrease by 20.6% for KB10O10D80, 38.2% for KB20O10D70, 44.1% for KB30O10D60, and 52.9% for KB40O10D50. At 50% engine load, the reductions are 14.8% for KB10O10D80, 22.2% for KB20O10D70, 44.4% for KB30O10D60, and 48.1% for KB40O10D50. At 75% engine load, the emissions drop by 20% for KB10O10D80, 37.1% for KB20O10D70, 45.7% for KB30O10D60, and 57.1% for KB40O10D50. Finally, at 100% engine load, KB10O10D80 has 17.9% lower emissions, KB20O10D70 has 35.9% lower emissions, KB30O10D60 has 41% lower emissions, and KB40O10D50 has 59% lower emissions compared to diesel. These numerical comparisons illustrate the significant reduction in hydrocarbon emissions as the proportion of Kusum biodiesel increases in the blend, demonstrating the effectiveness of these blends in reducing emissions relative to conventional diesel fuel.

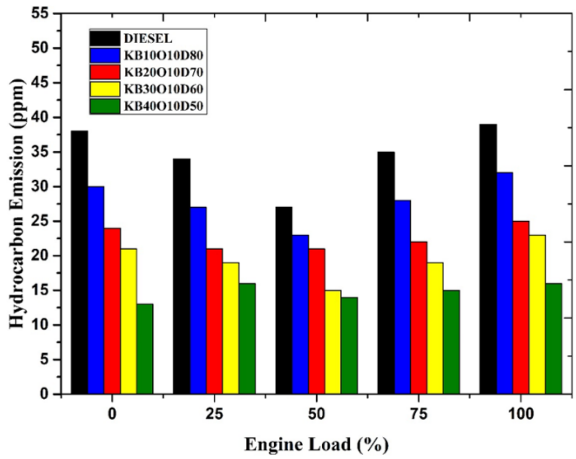

Figure 7: Hydrocarbon emission of KBOD blends at varied engine load

As Kusum biodiesel is introduced into the blend, emissions notably decrease due to biodiesel's higher oxygen content, which enhances combustion efficiency and reduces unburned hydrocarbons. The addition of N-octane also contributes to this improvement by increasing the octane number, which promotes more efficient combustion. The reduction in emissions increases from 10% Kusum biodiesel blend (KB10O10D80) to 40% Kusum biodiesel blend (KB40O10D50) and maximum reduction is observed in case of hydrocarbon emissions which is about 59% lower than that of pure diesel at full load condition. This consistent reduction of hydrocarbon emissions indicates that biodiesel content in the blends enhances the combustion process, which can be attributed to the oxygenated nature of biodiesel and the contribution of N-octane to the combustion quality. These factors not only help in reduction of hydrocarbon emissions but might also have a direct impact on Brake Thermal Efficiency (BTE) because of better combustion of fuel. Therefore, the use of more Kusum biodiesel in the fuel mix is beneficial to both the environment and performance, making it possible to use it in the reduction of emissions and the enhancement of engine efficiency.

4.6 Carbon monoxides

A comparison of the carbon monoxide (CO) emissions of the blends (KB10O10D80, KB20O10D70, KB30O10D60, and KB40O10D50) with that of pure diesel reveals a decrease in the emission at different engine loads were depicted in the figure 8. At 0% engine load, KB10O10D80 records a 7. 4% lower CO emissions than diesel, The KB20O10D70 has a 12. KB20O10D80 is down by 3%, KB30O10D60 is down by 16% and finally, KB40O10D50 is down by 21%. At 25% engine load, CO emissions decrease by 2.8% for KB10O10D80, 9.9% for KB20O10D70, 16.9% for KB30O10D60, and 23.9% for KB40O10D50. At 50% engine load, the reductions are 4.8% for KB10O10D80, 12.7% for KB20O10D70, 19% for KB30O10D60, and 27% for KB40O10D50. At 75% engine load, the CO emissions drop by 14.7% for KB10O10D80, 17.6% for KB20O10D70, 19.1% for KB30O10D60, and 23.5% for KB40O10D50. At 100% engine load, KB10O10D80 has 13.8% lower emissions compared to diesel, while KB20O10D70 shows an 8.5% decrease, KB30O10D60 shows an 18.1% decrease, and KB40O10D50 shows a 13.8% decrease. These numerical comparisons illustrate the general trend of reduced CO emissions with increasing Kusum biodiesel content, highlighting the potential of these blends to lower CO emissions relative to conventional diesel fuel.

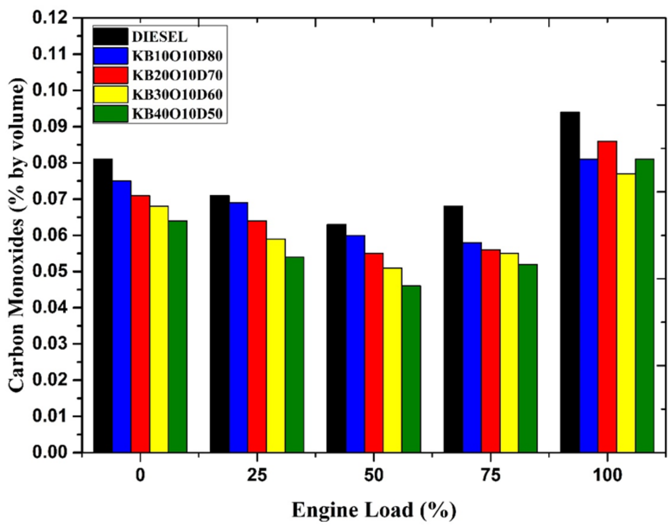

Figure 8: Carbon monoxide emission for KBOD blends across varied engine load

The decrease in carbon monoxide emissions with increase in Kusum biodiesel content can be explained by the following factors of fuel properties and combustion process. Kusum biodiesel has higher oxygen content than the normal diesel, and this results to efficient combustion and hence less production of CO which is associated with incomplete combustion. Because of the incorporation of oxygen in the biodiesel molecules, there is better oxidation of carbon during the combustion process thus reducing on the emission of CO. In the same regard, the addition of N-octane in the blends enhances the fuel's octane number, which enhances combustion efficiency through stable and efficient combustion especially under varying load conditions. Consequently, blends containing a higher percentage of Kusum biodiesel and N-octane have better combustion characteristics and reduced CO emission. This is in concordance with the observed decrease in emissions as demonstrated by the biodiesel containing oxygenated biodiesel and the improved combustion characteristics from N-octane in relation to pure diesel fuel.

V. CONCLUSION

The study demonstrates that the incorporation of Kusum biodiesel and Octanol blends into diesel fuel offers significant environmental benefits, notably in reducing key emissions such as carbon monoxide, hydrocarbons, and smoke, while simultaneously affecting brake thermal efficiency and brake specific energy consumption. The blends KB10O10D80, KB20O10D70, KB30O10D60, and KB40O10D50 exhibit a progressive reduction in emissions with increasing biodiesel content across various engine loads. However, the increase in biodiesel content also corresponds to a decrease in BTE and an increase in BSEC due to the lower calorific value of Kusum biodiesel compared to conventional diesel. The blend KB10O10D80, with the lowest biodiesel content, consistently performed closest to diesel in terms of thermal efficiency, showing the smallest efficiency decrease, while the highest blend, KB40O10D50, demonstrated the greatest reduction in BTE but the most significant improvements in emission reductions KB10O10D80 shows a Closest to diesel across all loads, showing the smallest decrease in BTE with a significant reduction in BTE, with a maximum decrease of 19.78% at 75% load.BTE decreases as the Kusum biodiesel content increases due to its lower calorific value compared to diesel. KB10O10D80 Shows a moderate increase in BSEC across all loads, indicating higher energy consumption compared to diesel. It exhibits the highest increase in BSEC, with up to an 11.66% rise at 100% load. BSEC increases with higher Kusum biodiesel content, primarily due to the lower energy density of biodiesel.

KB10O10D80 Shows a 17.9% to 21.1% decrease in HC emissions compared to diesel, depending on the engine load with highest reduction in HC emissions, with up to 65.8% lower emissions at 0% load. HC emissions decrease progressively as the Kusum biodiesel content increases, reflecting improved combustion. KB10O10D80 Shows a reduction in smoke emissions by 3.45% to 18.18% across various engine loads compared to diesel and exhibits the largest reduction in smoke, with up to 72.73% lower emissions at 0% load. Smoke emissions decrease significantly with higher Kusum biodiesel content due to better combustion and reduced soot formation. KB10O10D80: Shows a reduction in CO emissions by 2.8% to 14.7% across various engine loads compared to diesel. It demonstrates the most significant decrease in CO emissions, with up to 27% lower emissions at 50% load.CO emissions decrease consistently as the Kusum biodiesel content increases, indicating more complete combustion. KB10O10D80 Shows a slight increase in NOx emissions by 0.1% to 1.81% across different loads compared to diesel. It exhibits the highest increase in NOx emissions, with up to 5.36% higher emissions at 100% load. NOx emissions increase with higher Kusum biodiesel content, likely due to the higher in-cylinder temperatures and oxygen content leading to greater thermal NOx formation. These findings highlight the tradeoffs between environmental benefits and engine performance. The presence of n-Octanol in the blends contributes positively by enhancing combustion efficiency due to its oxygenated nature, which helps mitigate some of the efficiency losses associated with biodiesel's lower energy density. However, this mitigation is not sufficient to fully offset the reduced energy content of the higher biodiesel blends, particularly in KB40O10D50, which showed the greatest efficiency losses but also the highest reduction in CO, HC, and smoke emissions. The increase in NOx emissions with higher biodiesel content suggests that further optimization, possibly through engine tuning or the use of NOx reduction technologies, may be necessary to balance the benefits and drawbacks of these biodiesel blends. Overall, Kusum biodiesel and Octanol blends present a viable alternative to conventional diesel, offering a pathway to reducing emissions while maintaining acceptable engine performance, especially at lower biodiesel blend ratios.

Authors' Contributions

In this study, Kumaran P created the idea, conduction of experiment and Writing the original draft. Whereas Vignesh V and Vineeth A performed a literature review. Mahesh R and Sathiyaraj S done the supervision and validation of data

Competing Interests

The authors declare that they have no conflict of interest.

References

[1] S M. Veeraraghavan, et al., Influence of Hydrogen induction on performance and emission characteristics of an agricultural diesel engine fuelled with cultured Scenedesmus obliquus from industrial waste. Process Safety and Environmental Protection 187, 1576-1585, 2024

[2] K B. Parimi, et al., Investigation on a diesel engine fueled with hydrogen-compressed natural gas and Kusum seed biodiesel: Performance, combustion, and emission approach., Heat Transfer ,52(3), 2671-2693,2024

[3] Sakthimurugan, V., and S. Madhu. Novel Scenedesmus obliquus algae biofuel emission and performance characterise in Si-DLC coated diesel engine. Materials Today: Proceedings 77, 490-496, 2023

[4] S M. Veeraraghavan, et al., Waste-recovered quaternary blends: Enhancing engine performance through hydrogen induction by varied injection timing and pressure for sustainable practices., International Journal of Hydrogen Energy 87, 227-237, 2024

[5] K. T. Krishna, and V. Sakthimurugan, Various compression ratio strategies on introducing TiO2 in diesel-Palm oil blends in compression engine against diesel fuel for enhanced engine brake horsepower." AIP Conference Proceedings. Vol. 2822. No. 1. AIP Publishing, 2023

[6] C. Kishore, S. Yashvir, and N. Prateek, Comparative performance analysis on the DI diesel engine running on Karanja Kusum and Mahua methyl esters. Materials Today: Proceedings 46, 10496-10502,2021

[7] P. K. Praneel, and K. S. Vinod, Experimental analysis of diesel engine run on biodiesel derived from kusum oil. Materials Today: Proceedings 47, 2669-2672, 2021

[8] A. G. Poshetti, and M. S. Tandale. Experimental Study on CI Engine Performance for Optimum Blending Ratio of Blended Kusum Biodiesel. Advances in Energy Research, Vol. 2: Selected Papers from ICAER 2017. Springer Singapore, 2020

[9] A K. Yadav, A. Kumar, et al., Experimental investigations of performance and emissions characteristics of Kusum (Schleichera oleosa) biodiesel in a multi-cylinder transportation diesel engine. Waste and biomass valorization 8, 1331-1341, 2017

[10] K. Jayaraman, et al., Assessing the impact of sargassum algae biodiesel blends on energy conversion in a modified single-cylinder diesel engine with a silica-incorporated diamond-like coated piston. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects 46(1), 6882-6897, 2024

[11] J. Ahn, et al. Impact of Using n-Octanol/Diesel Blends on the Performance and Emissions of a Direct-Injection Diesel Engine. Energies 17(11), 2691, 2024

[12] K. Pachaiyappan, et al. Enhancing Combustion Efficiency: Utilizing Graphene Oxide Nanofluids As Fuel Additives With Tomato Oil Methyl Ester in CI Engines. Turkish Journal of Engineering, vol. 8, no. 4, pp. 720-8, 2024.
[13] J. Li, et al., Analysis of soot formation and oxidation processes in the diesel engine fueled by n-Octanol/biodiesel blends based on a detailed soot population balance model. Fuel, 358, 130376, 2024.
[14] M. Singh, et al. Effect of n-pentanol with novel water hyacinth biodiesel-diesel ternary blends on diesel engine performance and emission characteristics. Vietnam Journal of Chemistry ,2024.
[15] J. Li, et al. Blending n-Octanol with biodiesel for more efficient and cleaner combustion in diesel engines: a modeling study. Journal of Cleaner Production 403, 136877, 2023.
[16] G. Thippeshnaik, et al., Experimental investigation of compression ignition engine combustion, performance, and emission characteristics of ternary blends with higher alcohols (1-Heptanol and n-Octanol)., Energies 16(18), 6582, 2023
[17] AI. El -Seesy, et al., Enhancement of the combustion and stability aspects of diesel-methanolhydrous methanol blends utilizing n-octanol, diethyl ether, and nanoparticle additives. Journal of Cleaner Production 371, 133673, 2022
[18] M. Aneeque, et al., The combined effect of alcohols and Calophyllum inophyllum biodiesel using response surface methodology optimization., Sustainability 13.13 (2021): 7345.
[19] L. Atepor, The Effect of Bitter Kola (Garcinia) Biodiesel and n-Octanol Additives on Performance, Emission and Combustion Characteristics of Diesel Engines. Sustainable Education and Development 9. Springer International Publishing, 2021.
[20] S. Kodate, Vitthal, Y. Ajay Kumar, and G. N. Kumar. Combustion, performance and emission analysis of preheated KOME biodiesel as an alternate fuel for a diesel engine. Journal of Thermal Analysis and Calorimetry 141(6), 2335-2345, 2020
[21] B S. Chauhan, Naveen Kumar, and Haeng Muk Cho. A study on the performance and emission of a diesel engine fueled with Jatropha biodiesel oil and its blends. Energy 37(1), 616-622, 2012
[22] A. Singh, et al., An experimental investigation of emission performance of heterogenous catalyst jatropha biodiesel using RSM. Case Studies in Thermal Engineering 25, 100876, 2021
[23] IM R.Fattah, et al. Biodiesel production, characterization, engine performance, and emission characteristics of Malaysian Alexandrian laurel oil., RSC advances 4(34), 17787-17796, 2014
[24] J. Padmanaban, et al. Sustainability study and SWOT analysis of mixed biofuel blends in engine at various injection pressure analysed by experimentally and statistically., Scientific Reports 14(1), 31574, 2024
[25] D. Petkovi´c, et al. Neuro fuzzy estimation of the most influential parameters for Kusum biodiesel performance., Energy 229, 120621, 2021
[26] O. Khan, et al. Modelling of compression ignition engine by soft computing techniques (ANFIS-NSGA-II and RSM) to enhance the performance characteristics for leachate blends with nano-additives., Scientific Reports, 13(1), 15429, 2023.