Environmental Research and Technology
https://ert.yildiz.edu.tr - https://dergipark.org.tr/tr/pub/ert
DOI: https://doi.org/10.35208/ert.1341951

Research Article

Enhancement of the environmental bio-economy by investigating a sustainable cerbera odollam biodiesel at a low heat rejection engine

Anbazhagan RAMANUJAM*, Naveenchandran PANCHACHARAM

Department of Automobile Engineering, Bharath Institute of Higher Education and Research, Chennai, India

ARTICLE INFO

Article history
Received: 12 August 2023
Revised: 09 September 2023
Accepted: 16 September 2023

Key words:
Biodiesel; Bio economy; Diesel engine; Cerbera odollam seed; Nano coating; Low heat rejection engine

ABSTRACT

It is essential to maintain the environment by preserving the ecological balance of the area and keeping an eye on emission regulations. It's common knowledge that fossil fuels are the backbone of the transportation industry. Over time, the atmospheric concentrations of carbon and nitrogen oxides have risen dramatically due to human activities, particularly the burning of fossil fuels at excessive rates. Long-term sustainability may be attainable with the implementation of a bio-based, circular economy. Fears of a future fuel shortage and the negative effects on the environment spurred researchers to search for more sustainable energy sources. Renewability, reduced emissions, biodegradability, and better lubricating characteristics are just some of the reasons why biodiesel is becoming increasingly popular as a viable alternative to petroleum diesel. In this research paper, biodiesel extracted from cerbera odollam seeds was tested for its performance and emission characteristics on a low-heat rejection diesel engine with its piston coated with nano coating. The results were compared with those of a standard diesel engine, BCO25 at coated piston engine enhances break thermal efficiency by over 5.5%, consumes less fuel by 6.4%, reduces CO by 5.9%–10.7%, and reduces UBHC by 4% to 8.5%.

Cite this article as: Ramanujam A, Panchacharam N. Enhancement of the environmental bio-economy by investigating a sustainable cerbera odollam biodiesel at a low heat rejection engine. Environ Res Tec 2023;6(4)308–316.

INTRODUCTION

The preservation of the regional ecological balance and the implementation of vigilant emission controls are considered to be of utmost importance in ensuring environmental protection. The successful transition to a circular bio-economy can be achieved through the incorporation of global inclusiveness in the establishment of an organizational framework. This framework would be responsible for facilitating knowledge sharing, establishing global testing standards, evaluating the demand and supply of bio-based products, and providing support for research and development in biotechnology with the aim of commercialization [1].

The global bio-economy summit provides a definition of bio economy as the utilization of biological resources, implementation of new biological processes, and adherence to sustainable principles to facilitate the creation and provision of goods and services across many economic sectors, all of which are founded on knowledge. This concept elucidates that the bio economy is founded upon two fundamental pillars: resource efficiency and the substitution of fossil fuel-derived feedstock, as well as advancements in the field of biotechnology. Therefore, the bio economy enhances the worth of biomass resources, and an examination of the economic advantages of a specific resources [2, 3].

***Corresponding author.**
*E-mail address: anbazhaganbiher@gmail.com

Published by Yıldız Technical University Press, İstanbul, Türkiye

At now, the majority of biodiesel production in the commercial sector mostly relies on edible oils, notably soybean oil, rapeseed oil, and palm oil, as the primary feedstock for the synthesis of fatty acid methyl esters. Hence, biodiesel is engaged in a competition for scarce land resources with the food business, as both sectors rely on the cultivation of the same oil crops. Consequently, the current practice involves allocating arable land for the cultivation of fuel crops rather than for food production. Consequently, the increased cost of edible oil will result in a higher price for biodiesel, rendering its production economically impractical when compared to petroleum-based diesel fuel. To address this challenge, numerous scholars have initiated investigations into more cost-effective and non-consumable oils as potential substitutes for biodiesel production feedstock [4, 5].

Despite the possibility of exaggerated price hikes in biodiesel and edible oils, the ongoing discourse about the allocation of feedstock production for either food or fuel persists. The practice of converting cooking oil into biodiesel has recently attracted attention and criticism from environmental advocates. The proliferation of edible oil crop plantations, necessary for the large-scale production of biodiesel, is associated with deforestation and ecological degradation [6, 7]. The production of biodiesel from vegetable oil introduces a conundrum in balancing the demands of energy consumption and nutritional requirements. The current situation is characterized by a scarcity of available land, which has led to a competition between the production of biodiesel from edible oil and other land-intensive activities. The aforementioned phenomenon is currently observed in various regions across the globe, wherein extensive areas of land are being utilized for the cultivation of oil crops as a direct response to the increasing need for the production of biodiesel. The utilization of biodiesel derived from edible oils as a substitute for petroleum diesel oil possesses the capacity to deplete the global reserves of edible oils over an extended period of time [8, 9].

Researchers worldwide have conducted numerous studies to explore sustainable and renewable feed stock for the manufacture of biodiesel, aiming to address this discouraging issue. Second-generation biofuels encompass the utilization of waste oil to produce biodiesel. The feedstock utilized in second-generation biofuel production comprises non-edible plant sources, including jatropha, rubber seed, jojoba, tobacco seed, cerbera odollam, neem, candlenut, mahua, karanja, and yellow oleander. In the manufacturing of biodiesel, animal fats such as chicken fat, swine lard, and cattle tallow can also be utilized. In recent years, there has been a growing interest in utilizing waste edible oils, such as used cooking oils, as viable for the creation of biodiesel [10–12].

To effectively address sustainability challenges, it is imperative to establish a bioeconomy that is truly sustainable, rather than simply a bioeconomy. The present state of the bioeconomy continues to heavily depend on non-renewable energy sources and fossil-derived raw materials, such as nitrogen fertilizers, organic chemicals, and polymers, which are primarily derived from petroleum oil and gas. The establishment of a sustainable bioeconomy encompasses more than simply replacing non-renewable fossil resources with renewable alternatives. It necessitates the implementation of sustainable practices in the production of biomass feedstock, the conversion of biomass, and the development of sustainable bio-based products [13, 14].

The implementation of a circular economy that is based on bio-resources has the potential to contribute significantly to the attainment of sustainable development in the long run. This paper outlines five ecological principles that govern the utilization of biomass within a circular bioeconomy. The principles encompassed in this framework involve the conservation and rehabilitation of ecosystems, the avoidance of unnecessary products and the minimization of waste for essential items, the prioritization of biomass resources for basic human needs, the utilization and recycling of by-products from ecosystems, and the adoption of renewable energy sources with a focus on reducing energy consumption. The implementation of these concepts necessitates a comprehensive overhaul of our economic framework, encompassing policy reforms, technological advancements, organizational restructuring, shifts in social conduct, and market dynamics [15, 16].

The potential influence of biofuels on heat and electricity applications is expected to be substantial in the foreseeable future. Despite notable progress in diesel engine technology, the thermal efficiency of a traditional diesel-fueled engine continues to fall short of 35%. The primary cause of this phenomenon can be traced to the dissipation of heat from the engine. For several years, there has been a notable emphasis on the adoption of low heat rejection (LHR) engine technology as a strategy to mitigate heat dissipation from engines [17, 18]. In the study conducted by [19] the NOx emission saw a notable rise during engine running as a result of the synergistic effects of oxygenated biodiesel and ceramic coating applied to the piston crown. The findings indicate that the utilization of a 15% Exhaust Gas Recirculation system with a Thermal Barrier Coating (TBC) Piston in a normal diesel engine fuelled by Rape seed biodiesel leads to a reduction of 3.5% in brake thermal efficiency. Additionally, there is an observed rise of 2.8% in hydrocarbon emissions, 4% in carbon monoxide emissions, 2% in smoke emissions, and 6.2% in nitrogen oxide emissions.

The experiment employed free fatty acid methyl ester biodiesel from discarded frying oil. Biodiesel fuel works in diesel engines without modification since its qualities are comparable to diesel fuel. Thermal barrier coating is yttrium-stabilized zirconia. Experimentally, B20 was the best biodiesel-diesel blend since it possessed diesel-like qualities and reduced emissions. This study used a greaves diesel engine with and without heat barrier coating. In the diesel engine without thermal barrier coating, all biodiesel blends had lower braking power and higher brake specific fuel consumption than diesel fuel across the load range. All biodiesel mixes emit lower HC, CO, and greater CO2 and NOx than diesel [20, 21]. Various types of coatings, such as yttrium-stabilized zirconia, magnesium-stabilized zirconia, and gadolinium zirconate, were employed in the experimental procedure involving the utilization of soup nut biodiesel. The performance of biodiesel in terms of engine fuel consumption and emission efficiency was evaluated on a coated engine [22].

Diethyl ether (DEE) on the performance and emissions of a thermal-barrier-coated (TBC) engine running on papaw) and eucalyptus oil mixes. The DEE-adapted CPME30Eu70 mix had 32.2% BTE, while diesel had 31.8%, 1.2% more than at normal operation. Compared to a non-coated CPME30Eu70 engine, DEE lowered BSEC and BSFC by 8.9 and 7.2%, respectively. DEE-CPME30Eu70 reduced nitrogen oxide emissions. After DEE addition, CPME30Eu70's carbon monoxide and hydrocarbon emissions were 0.195% vol. and 38 ppm, 13.3 and 5.1% lower than with a compression ignition engine. DEE enhanced CPME30Eu70's atomization and spray. The CPME30Eu70-powered engine also improved performance and emissions [23, 24]. Ceramic TBCs insulate the base material and safeguard the source at high temperatures. This study examines 500-micron-thick yttrium-stabilized zirconia (YSZ). Plasma-sprayed bond coat. Diesel and mahua biodiesel are tested in a diesel engine under varied loads. This study shows brake thermal efficiency increases with BSFC decrease. The LHR engine emits more NOx but less HC and CO [25].

The main aim of this study is to assess the viability of employing biodiesel derived from Cerbera odollam oil (BCO) as a potential alternative energy source for boiler and industrial fuel applications. In order to address the issues pertaining to the performance and emissions of biodiesel-derived crude oil (BCO) in a diesel engine, the implementation of a thermal barrier coating on the piston head is considered to be of great significance. In this study, the utilization of a zirconia nano-coated piston is examined in the context of a single-cylinder diesel engine as low hear rejection (LHR) engine. The primary objectives of this investigation are to assess the benefits of utilizing the zirconia nano-coated piston in terms of reducing exhaust pollution, enhancing engine performance, and improving fuel consumption efficiency. In this experiment, the biodiesel derived from Cerbera odollam oil was blended with diesel at volume ratios of 25% and 50%. The performance and exhaust emission characteristics of these blends were assessed using the normal and LHR pistons testes at diesel engine.

MATERIAL AND METHODS

The Apocynaceae family includes the tree that is commonly known as the cerbera odollam. The seed of this noxious, fibrous-kernelled fruit contains a substantial quantity of oil. The fruit itself is deadly. Due to the fact that cerbera odollam contains oil that is inedible, this fruit could be considered for use as a source of non-edible feedstock in the manufacturing of biodiesel [26]. The height of these evergreen trees may range from 6 to 15 meters; have dark green, spiraling leaves; and egg-shaped fruits, which are 5 to 10 centimeters in length. The spirals of glossy dark green leaves have an ovoid form. The blooms have a pleasant aroma and have a white, five-lobed tubular corolla that is between 1.2 and 2.0 inches in diameter, with a pink or red throat.

Table 1. Properties of base diesel and biodiesel of cerbera odollam oil

Properties of fuel	Units	Diesel	Biodiesel of cerbera odollam oil
Calorific value	MJ/kg	45.5	38.5
Density	kg/m^3	832	847.9
Kinematics viscosity	mm^2/s	2.82	3.15
Cetane number	-	55	51
Flash point	ºC	64	121

Cerberin, a powerful cardiac glycoside, may be found in both the leaves and the fruits, making them very toxic. Extraction of glycosides from the seeds has anti-heart failure activity. There are few cases when the trunk bark or leaves are used as a purgative, however this is only done with extreme care due to its high toxicity. Cerbera odollam, known locally as cerbera odollam, is one of the few oil-producing plants. Cerbera odollam thrives in coastal salt swamps and creeks in south India and along riverbanks in southern and central Sri Lanka, Vietnam, Myanmar, Malaysia. Cambodia, and Madagascar. Malaysian roadside decorative trees are numerous. The plant's toxicity dominated. The plant's oil can be utilized as biodiesel feedstock because decantation can remove the toxin (cerberin). The poison only harms when digested [4, 11]. The oil content derived from the seeds of Cerbera odollam amounts to 54%. The predominant fatty acid found in cerbera odollam oil is oleic acid, accounting for 48.1% of the content. This is followed by palmitic acid at 30.3%, linoleic acid at 17.8%, and stearic acid at 3.8% [27].

The findings pertaining to the characteristics of cerbera odollam methyl esters indicate that the viscosity exhibited a value of around 3.15 mm^2/s, the density was measured at 847.9 kg/m^3, the flash point was determined to be 214 °C, the acid value was found to be 0.4 mg KOH/g, the oxidation stability was observed to be 6.35 hours, the FAME content accounted for 97.77% w/w, and the heating value was calculated to be 40.49 MJ/kg. Upon conducting an analysis of these qualities, it has been determined that there exists a significant potential for the manufacture of biodiesel from this particular seed [11]. Table 1 displays the Properties of Base Diesel and Biodiesel of Cerbera odollam oil.

The thermal barrier coating (TBC) system reduces substrate material heat load and improves thermal efficiency. The TBC system can insulate the piston crown by coating diesel engine pistons. The piston heat load could be reduced by heat lost through the piston. The piston substrate can resist lower temperatures than the covering, which is ceramic-based and strong. Coating also reduces fuel consumption and pollution [19, 28]. The classic double-layer structure thermal barrier coating has a ceramic topcoat and a metallic bond coat. Due to its modest expansion coefficient, the bond coat substance, an intermetallic alloy, helps the ceramic topcoat and substrate adhere. Internal stress between the ceramic covering and substrate is reduced by high-temperature oxidation resistance. The ceramic topcoat may effectively isolate heat in the combustion chamber because it has a lower thermal conductivity than the substrate. Thus, the piston substrate's temperature drops, improving piston reliability. The chamber's thermal efficiency increases as its temperature rises [29].

To enhance thermal efficiency in diesel engines and mitigate heat loss during combustion, the integration of piston heat insulation has been implemented. The significance of ceramic insulation techniques is increasing as the global community seeks more effective methods to comply with emission standards and conserve fuel resources. Ceramics has excellent insulating properties due to their inert nature. In this context, it is worth mentioning that yttrium-stabilized zirconia and alumina are widely utilized as materials for thermal barrier coatings [22, 25].

The process of plasma spraying involves the utilization of metal powder as its primary input material. Coating materials, often in the form of powders, are delivered into a plasma jet, whereby their particles undergo a process of melting and subsequent propulsion towards the target surface for the purpose of coating. The initial step in the deposition process involves the application of a 200-micron thick bond layer, composed of alumina, zirconia, and nickel, onto the aluminium alloy base grain of the piston. The term "bond coat" refers to the initial coating of paint that is applied. A thermal shield was fabricated with a bond coating comprising of alumina, zirconia, and nickel. The application of the bond layer was facilitated by the utilization of plasma spraying technique. Bond coatings have the potential to enhance the adhesion of oxide coatings to various surfaces. The adhesion between the coating and the substrate is a crucial factor in the fabrication of a thermal shield. Subsequently, a layer of zirconia with a thickness of 250 micrometres is applied onto the surface of the piston. The discrete particles of powder possess an approximate diameter of 50 micrometres. The objects are driven at high velocities of the flame, undergoing instantaneous melting and subsequent solidification.

Experimental Details

The necessity of employing a two-step procedure for the synthesis of biodiesel from Cerbera odollam oil can be attributed to its elevated free fatty acid concentration. The acid esterification process was conducted using a molar ratio of 10:1 of methyl alcohol to oil for a duration of 120 minutes. Sulphuric acid, with a concentration of 2%, was employed as the acid catalyst. The speed of the magnetic stirrer was maintained at a constant rate of 500 rpm to mitigate limitations on mass transfer. The objective of this technique was to decrease the acid value of the input oil. After the acid-esterification procedure, a settling period of four hours was provided for the reaction mixture. The cerbera odollam oil that had been esterified was subsequently subjected to the transesterification procedure. Alkali homogeneous catalysts, such as NaOH and KOH, offer several advantages compared to other catalysts. These benefits include the ability to conduct the process at atmospheric pressure, with a very short reaction time of 30–90 minutes, at low temperatures ranging from 40–60 °C. Additionally, the use of alkali homogeneous catalysts is cost-effective and leads to high conversion rates. Upon completion of the procedure, the emergence of two distinct layers becomes apparent. The uppermost stratum consisted of biodiesel, whereas glycerol occupied the lowermost stratum. The glycerol that accumulated at the bottom was extracted, while the biodiesel was afterwards subjected to a purification washing operation, so concluding the transesterification process and yielding pure biodiesel.

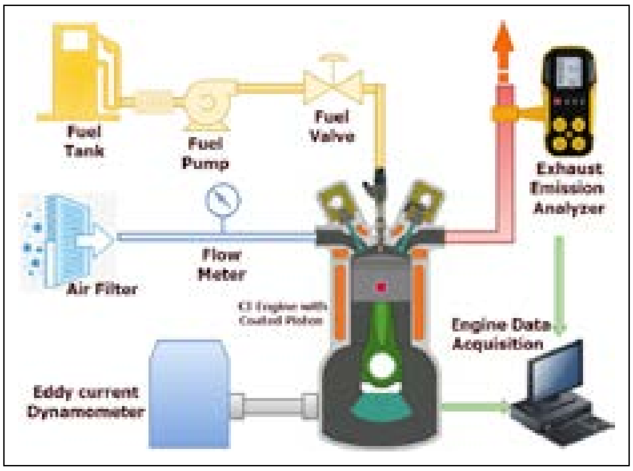

Figure 1. Experimental setup.

An experimental investigation was conducted to evaluate the performance of a diesel fuel blend consisting of Cerbera odollam oil in a single-cylinder, direct-injection, constant-speed engine equipped with a piston coated with a nano material. Figure 1 illustrates the experimental setup. The eddy current dynamometer was utilized to impose a spectrum of loads on the engine, spanning from zero to one hundred percent. The engine power output of 4.4 kW is utilized to its maximum capacity, exerting a force of 1.1 kW on each testing mixture. The adjustment of engine loads can be achieved through hand manipulation with an eddy current dynamometer. In this experimental study, the measurement of airflow was conducted utilizing a calibrated burette, whereas the measurement of fuel flow was carried out using a calibrated aperture situated on an air drum. Table 2 describes the instruments and its details used for the investigation. The researchers also made note of the amount of diesel and biodiesel blends used in the studies of fuel flow. Through the utilization of AVL software, a diverse range of measurements and outcomes were obtained during the operation of the test rig.

Biodiesel of Cerbera odollam oil (BCO), was blended with diesel at different ratios of 25% and 50% on a volume basis as BCO25 and BCO50. Further, the biodiesel tested at low heat rejection engine (LHR) for the same blend as BCO25@LHR and BCO50@LHR. This paper examines the diesel engine performance and emission characteristics of biodiesel blends at uncoated piston and coated piston.

Table 2. Details of test instrumentation

Measurement	Range	Accuracy	Instrument
Load	–	+0.1 kg to −0.1 kg	Load cell
Speed	0–10000 rpm	±10 rpm	Digital tachometer
Fuel quantity	0–50 cm^3	±0.1 cm3	Burette measurement
Carbon monoxide	0 to 20000 ppm	±10 ppm	AVL exhaust gas analyser, NDIR technique
Hydro carbon	0 to 15%	±0.03%	AVL exhaust gas analyser, NDIR technique
Nitrogen oxides	0 to 5000 ppm	±10 ppm	AVL exhaust gas analyser, NDIR technique
Smoke	0–100%	±1 %	AVL smoke meter

RESULTS AND DISCUSSION

Figure 2 displays the brake thermal efficiency (BTE) fluctuation across the engine power for the cerbera odollam blends. BCO25@LHR performed more than 5.5% increase in Break thermal efficiency due to LHR engine's in-cylinder temperatures, combustion efficiency, and ignition timing are all enhanced by the increased vaporization and air-fuel atomization. Also, BCO25@LHR over performed the same fuel by 2 to 6.6% more at break thermal efficiency. In addition to boosting power generation for constrained diesel volume and brake thermal performance, the nano coating also reduces the reject rate in the combustion chamber. The increase in load resulted in a corresponding growth in the brake thermal efficiency due to reduced energy losses. BCO25 and BCO50 have less thermal efficiency by 1.8% and 5.9% compared to base diesel. Furthermore, it was observed that when the blend ratio increased, there was a corresponding decrease in brake thermal efficiency. When biodiesel is used with diesel, it results in an increase in viscosity and a decrease in volatility. The occurrence of incomplete combustion and poor brake thermal efficiency may be attributed to the inadequate spray pattern, resulting in the uneven dispersion of fuel within the combustion chamber. In addition, the low calorific value of cerbera odollam biodiesel played a role in the decrease of brake thermal efficiency [4, 27].

Several factors significantly affect the Specific Fuel Consumption (SFC), which includes the fuel's density, heating value, viscosity and cetane value. The LHR coating on the combustion components reduces the ignition delay time, the engine uses less fuel consumption than a standard diesel engine. BCO25@LHR consumed less fuel by 6.4% compared to base diesel fuel and 3.5% than the same blend at non coated engine. The higher viscosity and density of BCO50 produce poor atomization, leading to a rise in SFC about 6%. In response to varying engine loads, different fuel samples exhibit varying patterns of specific fuel consumption, as seen in Figure 3. The SFC decreases noticeably at mid-range of engine power, and then decreases further as the load increases. Because of an increase in engine power under higher loads and a corresponding decrease in heat dissipation ratios, we observe this phenomenon. Diesel's higher calorific value and lower density result in a lower specific fuel consumption. Because biodiesel has a lower calorific value than conventional diesel, blending it increased the blends' fuel consumption [11, 29].

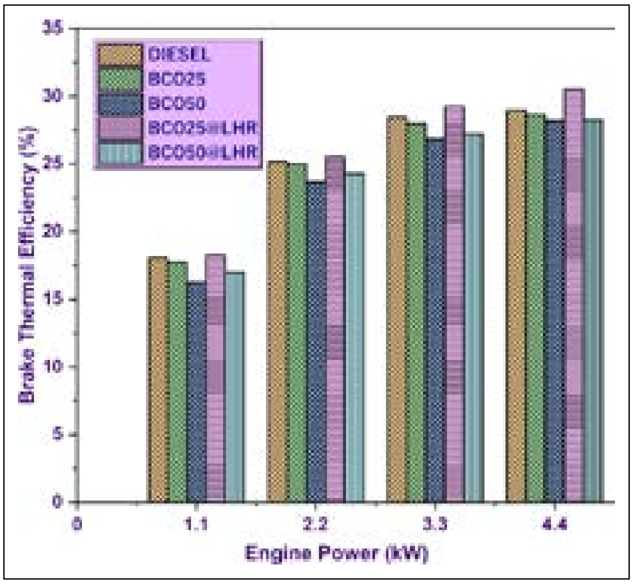

Figure 2. Study of brake thermal efficiency with BCO.

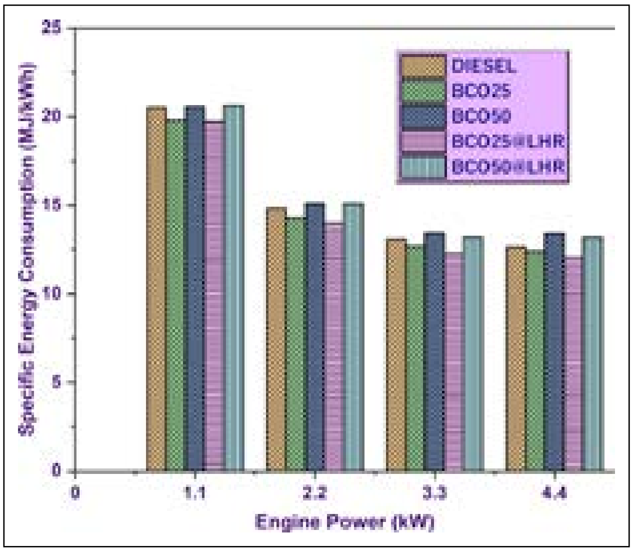

Figure 3. Study of fuel consumption with BCO.

Figure 4 illustrates the range of carbon monoxide (CO) emissions observed across several fuel samples in relation to engine load. CO emissions of the fuel samples exhibit an upward trend until reaching maximum load, with a decline until 2.2kW of engine power. The utilization of

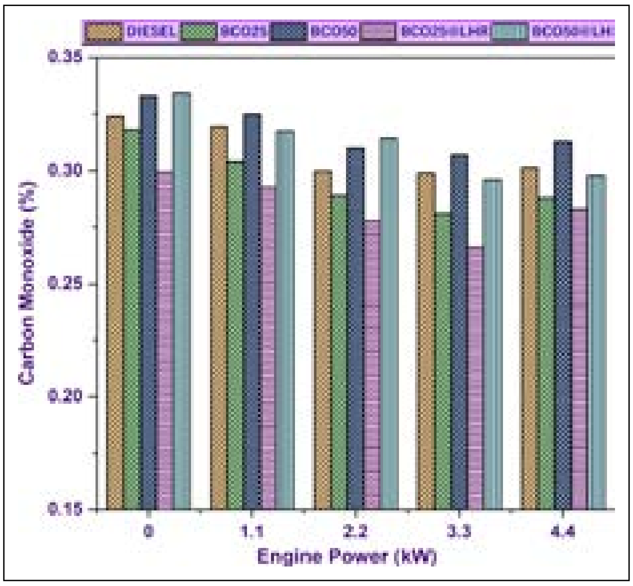

Figure 4. Study of carbon monoxide emissions with BCO.

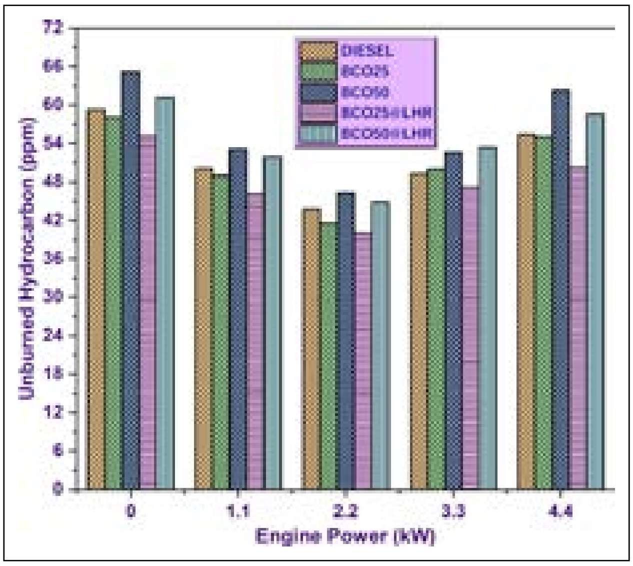

Figure 5. Study of unburned hydrocarbon emissions with BCO.

low loads in engines results in the maintenance of low gas temperatures, hence causing incomplete combustion in the gas phase and subsequently leading to elevated levels of carbon monoxide emissions [30]. An elevated temperature of the gas within the cylinder at load leads to a higher rate of CO oxidation, resulting in reduced emissions of CO. BCO25 blends performed better at different engine loads, with 6 to 10% reduced CO emissions compared to diesel fuel. At BCO25@LHR blends, CO reduced by 5.9% to 10.7% with respect to all loads compared with base fuel. The rationale behind this phenomenon lies in the fact that biodiesel fuels exhibit a greater oxygen content in comparison to conventional diesel fuel. As a result, the oxidation process is enhanced, leading to a reduction in carbon monoxide emissions [9, 31].

Figure 5 illustrates a between the emissions of unburned hydrocarbon (UBHC) and the rise in load across all fuel types. The primary factors contributing to hydrocarbon emissions are inadequate fuel-air mixing, suppression of the oxidation process, and an elevated carbon-to-oxygen ratio. The occurrence of this phenomenon can be attributed to the existence of fuel-rich mixes and a deficiency of oxygen necessary for combustion under increased loads. Moreover, the likelihood of incomplete combustion in an engine increases when additional fuel is introduced to the system [4, 32]. These conditions arise as a result of increased engine loads, leading to a corresponding increase in hydrocarbon emissions. The findings of the study indicate that the utilization of mixed fuels resulted in a reduction of hydrocarbon emissions in comparison to the emissions generated by pure diesel fuel. BCO25 blends performed better at different engine loads, with 5 to 8.5% reduced UBHC emissions compared to diesel fuel. At BCO25@LHR blends, UBHC reduced by 4% to 8.5% with respect to all loads compared with base fuel. The acceleration of soot oxidation at high temperatures is attributed to the elevated oxygen level within the combustion chamber [33].

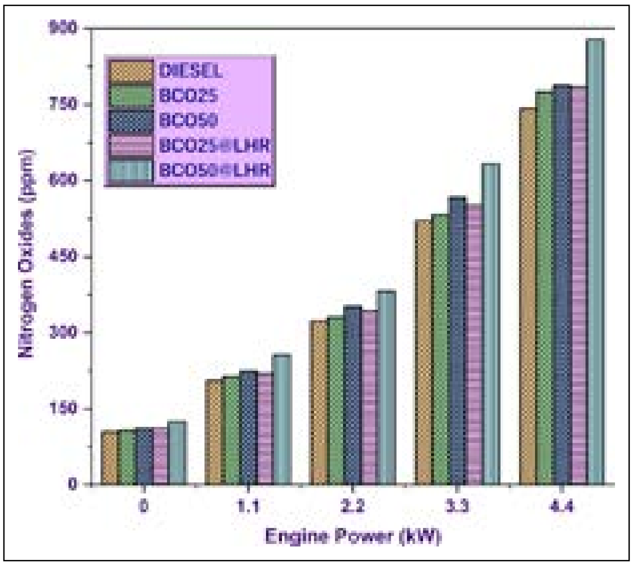

Figure 6. Study of nitrogen oxides emissions with BCO.

The emissions of nitrogen oxides exhibit an upward trend when the operating condition transitions from no load to full load. An observable phenomenon is that an increase in load leads to a corresponding increase in combustion temperature, which subsequently results in elevated levels of nitrogen oxide emissions. The primary generation of NOx occurs within engines due to the increased heat generated during the power stroke. The primary by products generated during the internal combustion process within the cylinder are nitrogen oxides, resulting from the chemical reaction between nitrogen and oxygen [22, 25]. In contrast to diesel fuel, biodiesel exhibits a higher propensity for nitrogen oxide emissions due to its increased oxygen content. Figure 6 illustrates the levels of nitrogen oxide emissions resulting from the combustion of diesel and biodiesel mixtures. BCO25, BCO50 recorded with an increase of 4.6% and 8.8% than the diesel. Whereas at LHR, same blends recorded more than 6% and 18% than the base diesel due to higher combustion temperature. The use

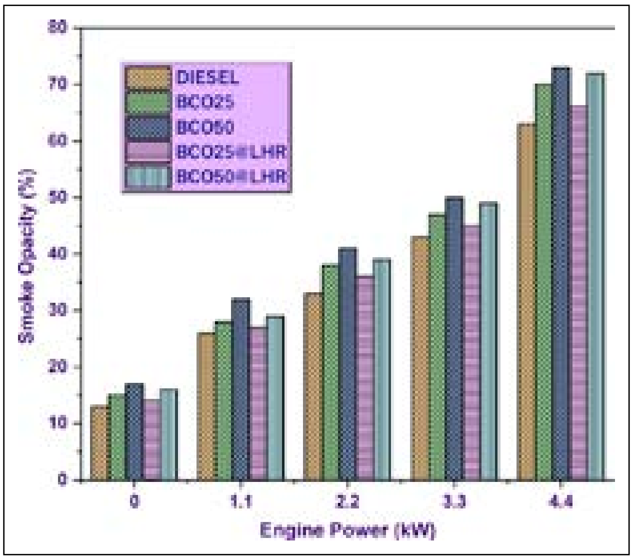

Figure 7. Study of smoke emissions with BCO.

of bio diesel at low heat rejection engine has been found to raise the higher combustion temperature, accelerate the combustion rate, and improve the heat transfer rate, resulting in a reduction in nitrogen oxides emissions [34].

The quick reaction between the hydrogen molecules in the liquid fuel and oxygen results in the production of smoke due to insufficient oxygen to facilitate the complete combustion of the remaining carbon. The qualitative interpretation of this phenomenon pertains to the concentration of particles within the exhaust stream that possess a diameter significant enough to cause scattering of incident light upon interaction. From Figure 7, BCO25, BCO50 recorded the smoke with an increase of 7.1% to 24.2% than the diesel. Whereas at LHR, same blends recorded more than 4% and 14% than the base diesel due to higher combustion temperature. It is conceivable that increased loads may result in a greater number of fuel molecules actively engaging in oxidation reactions. Smoke is generated in the fuel-rich section of the cylinder due to the elevated temperature and pressure resulting from the lack of oxygen. The utilization of biodiesel fuel mixes resulted in a significant reduction in smoke emissions [35]. The rationale behind this phenomenon is in the elevated oxygen level found in biodiesel blends, which consequently enhances the efficiency of oxidation and combustion processes. When the fuel injection pressure is raised, the fuel blends are better atomized, leading to cleaner burning and less smoke. Diesel mix products have bigger shattered droplet sizes due to the presence of LHR engine laminates, which reduces ignition centres and smoke by increasing cylinder temperature [36].

CONCLUSION

Bio economy is the study of the economic benefits of using a certain resource, which raises the value of biomass resources. This study evaluated the efficiency and emissions of diesel fuel made from Cerbera odollam seeds using a low-heat rejection diesel engine with a piston covered with Nano coating. The investigation compared the findings to those of a conventional diesel engine and analysed the most important characteristics, as discussed below.

- BCO25@LHR performed more than 5.5% increase in break thermal efficiency than the base diesel. Also, same blend at LHR over performed the same fuel by 2 to 6.6% more at thermal efficiency.
- BCO25@LHR consumed less fuel by 6.4% compared to base diesel fuel and 3.5% than the same blend at non coated engine. The higher viscosity and density of BCO50 produce poor atomization, leading to a rise in SFC about 6%.
- At varying engine loads, BCO25 blends outperformed diesel fuel while emitting 6-10% less CO. BCO25@LHR blends reduced CO by 5.9%-10.7% relative to base diesel across all loads.
- BCO25 blends performed better at different engine loads, with 5 to 8.5% reduced UBHC emissions compared to diesel fuel. At BCO25@LHR blends, UBHC reduced by 4% to 8.5% with respect to all loads compared with base fuel.
- NOx was found to be higher in the BCO25 and BCO50 than in the diesel, by 4.6% and 8.8%, respectively. However, the same blends showed increases of 6% and 18% over the standard diesel at LHR.
- The smoke was shown to increase the BCO25 and BCO50 values by 7.1% to 24.2% compared to the diesel. On the other hand, greater combustion temperatures at LHR led to higher readings for the identical blends, exceeding the base diesel by between 4 and 14 percent.

This idea clarifies that the bio economy is built in large part on maximizing resource efficiency and substituting feedstock not produced from fossil fuels. The diversification of the energy portfolio has the potential to reduce dependence on fossil fuels, particularly for countries that have a high reliance on oil imports. They have the potential to facilitate the formation of new markets and job possibilities for farmers, rural communities, and biofuel enterprises. Furthermore, these technologies provide the capability to reduce energy costs and improve energy accessibility in geographically remote or socioeconomically weak regions. The biodiesel extracted from Cerbera odollam seeds' performance and emission characteristics on a low-heat rejection diesel engine were able to meet the needs to achieve the bio economy.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] D. Nagarajan, D.-J. Lee, and J.-S. Chang, "Chapter 22 - Circular bioeconomy approaches for sustainability and carbon mitigation in microalgal biorefinery," S. Varjani, A. Pandey, T. Bhaskar, S. V. Mohan, and D. C. W. Tsang, (Eds.), Biofuels, Biochemicals, Elsevier, pp. 557–598, 2022. [CrossRef]

[2] Y. Lokko, M. Heijde, K. Schebesta, P. Scholtès, M. Van Montagu, and M. Giacca, "Biotechnology and the bioeconomy—Towards inclusive and sustainable industrial development," New Biotechnology, Vol. 40, pp. 5–10, 2018. [CrossRef]

[3] World Business Council for Sustainable Development, "Circular Bioeconomy," World Business Council for Sustainable Development, pp. 73, 2020.

[4] J. Kansedo, K. T. Lee, and S. Bhatia, "Cerbera odollam (sea mango) oil as a promising non-edible feedstock for biodiesel production," Fuel, Vol. 88(6), pp. 1148–1150, 2009. [CrossRef]

[5] J. Thamilarasan, V. Ravikumar, S. P. Raj Yadav, J. Yarlagadda, A. Kumar, S. Ramasubramanian, … B. Y. Asres, "Sustainability improvement of ethanol blended gasoline fuelled spark ignition engine by nanoparticles," Journal of Nanomaterials, Vol. 2022, Article 7793947. [CrossRef]

[6] J. Senthil Kumar, S. Ganesan, S. Sivasaravanan, S. Padmanabhan, L. Krishnan, and V. C. Aniruthan, "Effects of nano additives in engine emission characteristics using blends of lemon balm oil with diesel," IOP Conference Series: Materials Science and Engineering, Vol. 197(1), Article 012022. [CrossRef]

[7] V. Hariram, S. Seralathan, M. Rajasekaran, M. Dinesh Kumar, and S. Padmanabhan, "Effect of metallic nano-additives on combustion performance and emissions of DI CI engine fuelled with palmkernel methyl ester," International Journal of Vehicle Structures and Systems, Vol. 9(2), pp. 103–109, 2017. [CrossRef]

[8] S. Ganesan, S. Padmanabhan, S. Mahalingam, and C. Shanjeevi, "Environmental impact of VCR diesel engine characteristics using blends of cottonseed oil with nano additives," Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, Vol. 42(6), pp. 761–772, 2020. [CrossRef]

[9] V. S. Shaisundaram, M. Chandrasekaran, M. Shanmugam, S. Padmanabhan, R. Muraliraja, and L. Karikalan, "Investigation of Momordica charantia seed biodiesel with cerium oxide nanoparticle on CI engine," International Journal of Ambient Energy, Vol. 42(14), pp. 1615–1619, 2021. [CrossRef]

[10] A. P. Venkatesh, S. Padmanabhan, G. V. Rajveer, K. Yuvaja, and M. Muniyappan, "Effect of fuel injection pressure on the performance and emission analysis of Mahua Methyl ester in a single cylinder diesel engine," International Journal of Ambient Energy, Vol. 43(1), pp. 1556–1560, 2022. [CrossRef]

[11] Khairil, A. Rizki, Iskandar, Jalaluddin, A. S. Silitonga, H. H. Masjuki, and T.M.I. Mahlia"The potential biodiesel production from Cerbera odollam oil (Bintaro) in Aceh," MATEC Web Conferences, Vol. 159, Article 01049, 2018. [CrossRef]

[12] S. Padmanabhan, T. Vinod Kumar, M. Chandrasekaran, and S. Ganesan, "Investigation of Sapindus seed biodiesel with nano additive on single cylinder diesel engine," International Journal of Ambient Energy, Vol. 41(10), pp. 1106–1109, 2020.

[13] D. D'Amato, N. Droste, B. Allen, M. Kettunen, K. Lähtinen, J. Korhonen, ... A. Toppinen, "Green, circular, bio economy: A comparative analysis of sustainability avenues," Journal of Cleaner Production, Vol. 168, pp. 716–734, 2017. [CrossRef]

[14] P. Stegmann, M. Londo, and M. Junginger, "The circular bioeconomy: Its elements and role in European bioeconomy clusters," Resources, Conservation & Recycling: X, Vol. 6, Article 100029, 2020. [CrossRef]

[15] A. Muscat et al., "Principles, drivers and opportunities of a circular bioeconomy," Nat. Food, vol. 2, no. 8, pp. 561–566, 2021. [CrossRef]

[16] V. L. Mangesh, E. M. de Olde, R. Ripoll-Bosch, H. H. E. Van Zanten, T. A. P. Metze, C. J. A. M. Termeer, M. K. van Ittersum, and I. J. M. de Boer., "Green energy: Hydroprocessing waste polypropylene to produce transport fuel," Journal of Cleaner Production, Vol. 276, Article 124200, 2020. [CrossRef]

[17] K. K. Pandey, and S. Murugan, "A review of bio-fuelled LHR engines," International Journal of Ambient Energy, Vol. 43(1), pp. 2486–2509, 2022. [CrossRef]

[18] K. K. Pandey, and M. S., "Thermal and experimental analyses of thermal barrier coated pistons," International Journal of Modelling and Simulation, pp. 1–19, Preprint, 2023. doi: 10.1080/02286203.2023.2176676. [CrossRef]

[19] H. Tarigonda, V. Reddy Gangula, P. Ratnaraju, R. R. Doddipalli, and R. L. Krupakaran, "Effect of TBC, turbocharger and EGR on the performance of diesel engine using biodiesel," SAE Technical Paper 2022-28-0558, 2022. [CrossRef]

[20] V. Sankar, M. Ramachandran, G. Thampi, and M. K. Jayaraj, "Combined effects of thermal barrier coating and blending of diesel fuel with biodiesel in diesel engines," Materials Today Proceedings, Vol. 11(3), pp. 903–911, 2019. [CrossRef]

[21] S. Padmanabhan, K. Giridharan, B. Stalin , V. Elango, J. Vairamuthu, P. Sureshkumar, L. T. Jule, and R. Krishnaraj. "Sustainability and environmental impact of ethanol and oxyhydrogen addition on nanocoated gasoline engine," Bioinorganic Chemistry and Applications, Vol. 2022, Article 1936415, 2022. [CrossRef]

[22] C. Karthikeyan, K. L. Harikrishna, and N. Nallusamy, "Experimental investigation of TBC coated piston with various blends of biodiesel," Environmental Progress & Sustainable Energy, Vol. 42(4), Article e14065, 2023. [CrossRef]

[23] P. Murugesan, P. V. Elumalai, D. Balasubramanian, S. Padmanabhan, N. Murugunachippan, Asif Afzal, P. Sharma, K. Kiran, J. S. Femilda Josephin, E. G. Varuvel , T. T. Le, T. Hai Truong, "Exploration of low heat rejection engine characteristics powered with carbon nanotubes-added waste plastic pyrolysis oil," Process Safety and Environmental Protection, Vol. 176, pp. 1101–1119, 2023. [CrossRef]

[24] E. P. Venkatesan, P. Murugesan, S. Rajendran, P. Sekar, P. A. Remigious, and R. B. Durai Chinna, "Experimental studies on thermal-barrier-coated engine fuelled by a blend of eucalyptus oil and DEE," ACS Omega, Vol. 7(50), pp. 46391–46401, 2022. [CrossRef]

[25] R. Rajesh, C. V. B. Reddy, and B. D. Prasad, "Experimental investigation of YSZ coated piston crown on performance and emission features of LHR diesel engine with mahua Biodiesel," IOP Conference Series: Materials Science and Engineering, Vol. 998, Article 012054, 2020. [CrossRef]

[26] J. Lie, M. B. Rizkiana, F. E. Soetaredjo, Y.-H. Ju, and S. Ismadji, "Production of biodiesel from sea mango (Cerbera odollam) seed using in situ subcritical methanol–water under a non-catalytic process," International Journal of Industrial Chemistry, Vol. 9(1), pp. 53–59, 2018. [CrossRef]

[27] S. S. Dhillon, and K. T. Tan, "Optimization of biodiesel production via methyl acetate reaction from cerbera odollam," Advanced Energy Resources, Vol. 4(4), pp. 325–337, 2016. [CrossRef]

[28] S. Padmanabhan, C. Joel, L. Joel, O. Y. Reddy, K. G. D. S. Harsha, and S. Ganesan, "Evaluation of waste plastic pyrolysis oil performance with diethyl ether additive on insulated piston diesel engine," Nature Environment and Pollution Technology, Vol. 20(5), pp. 2079–2086, 2021. [CrossRef]

[29] Z. Shu, J. Deng, Z. Qian, C. Fei, S. Zhu, Y. Du, and K. Zhou, "Thermal analysis of mullite coated piston used in a diesel engine," Coatings, Vol. 12(9), Article 1302, 2022. [CrossRef]

[30] M. A. J. Selvam, R. Arunraj, T. M. Inbamalar, V. Kannagi, and S. Padmanabhan, "Exploration of performance and emission characteristics of soybean biodiesel blends on CI engine," in AIP Conference Proceedings, Vol. 2492, 2023. [CrossRef]

[31] S. Ganesan, S. Padmanabhan, J. Hemanandh, and S. P. Venkatesan, "Influence of substrate temperature on coated engine piston head using multi-response optimisation techniques," International Journal of Ambient Energy, Vol. 43(1), pp. 610–617, 2022. [CrossRef]

[32] M. Bhargavi, T. Vinod Kumar, R. Ali Azmath Shaik, S. Kishore Kanna, and S. Padmanabhan, "Effective utilization and optimization of waste plastic oil with ethanol additive in diesel engine using full factorial design," Materials Today: Proceedings, Vol. 52, pp. 930–936, 2022. [CrossRef]

[33] P. Sambandam, P. Murugesan, M. I. Shajahan, B. Sethuraman, and H. A. Hussein, "Sustainability and environmental impact of hydroxy addition on a light-duty generator powered with an ethanol gasoline blend," Journal of Renewable Energy and Environment, Vol. 9(2), pp. 82–92, 2022. [CrossRef]

[34] V. L. Mangesh, S. Padmanabhan, P. Tamizhdurai, and A. Ramesh, "Experimental investigation to identify the type of waste plastic pyrolysis oil suitable for conversion to diesel engine fuel," Journal of Cleaner Production, Vol. 246, Article 2020. [CrossRef]

[35] S. Ramkumar, M. Parthasarathy, and S. Padmanabhan, "Performance optimization of HCCI engine fueled with Tamanu methyl ether," The International Journal of Vehicle Structures and Systems, Vol. 11(2), pp. 149–153, 2019. [CrossRef]

[36] S. Padmanabhan, K. Karthikeyan, K. K. Nagachandrika, K. Giridharan, and G. Chakravarthi, "Evaluation and optimization of plastic pyrolysis blends performance on diesel engine with ethanol additive using full factorial design," The International Journal of Vehicle Structures and Systems, Vol. 14(3), pp. 348–355, 2022. [CrossRef]