Effect of Waste Pomegranate Peels Biodiesel on Performance and Emission Analysis of Diesel Engine

Santosh Kumar Yadav, Devesh Kumar*, Suraj, Suraj Singh, Priyankesh Kumar*, Varun Kumar Singh

Department of Mechanical Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur, Uttar Pradesh, India, 273010

*Corresponding author's e-mail: dkme@mmmut.ac.in, pkchaudhary860@gmail com

doi: https://doi.org/10.21467/proceedings.161.6

ABSTRACT

The effect of conventional fuels has been investigated for its sustainable effect on the progress of power generation, the industrial sector, agriculture, and other related needs. In daily routine, the diesel engine has been identified as an essential part of the power and energy sectors. Diesel engine exhaust emissions have negatively impacted living organisms' health. Biodiesel have been identified as a sustainable fuel source that can replace traditional petroleum-based diesel fuel. The present work is to investigate using pomegranate peels to extract the pomegranate peel oil by Soxhlet apparatus and then convert it into biodiesel with the help of the transesterification process.

Further, three different blending ratio mixtures with the help of pomegranate peel biodiesel (PPBD) were made on a volume basis, named PPBD 0 (FD 100%), PPBD 10 (10% biodiesel + 90% FD), and PPBD 20 (20% biodiesel + 80% FD), to check their performance and emission analysis on a single cylinder, four-stroke diesel engine. In diesel engines, the study investigated the system's performance concerning brake thermal efficiency (BTE) and brake-specific fuel consumption (BSFC). The study analyzed various emissions, including carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO_2), and nitrogen dioxide (NO_X), using a gas analyzer. The study results indicate that PPBD 20 is the most effective blending mixture in performance and emission reduction, making this fuel a potential substitute for fossil diesel.

Keywords: Pomegranate peels oil, Soxhlet apparatus, Transesterification process, Performance, and emission analysis

1 Introduction

The scenario shows that more energy is needed due to industrialization and an increased human population. Its access to energy mostly drives any nation's social and economic developments. The depletion of fossil resources highlights the need for sustainable, alternative, and renewable energy sources. Fundamentally, the application of fossil fuels is to blame for environmental concerns since they emit many pollutants and smoke when burned. Additionally, the mining of fossil fuels destroys vast areas; thus, alternative renewable fuels must be used instead. The fuel and energy crises and society's worries about the world's non-renewable energy resources sparked an interest in the search for alternative fuels. Vegetable oils and their derivatives are one of the most promising alternative fuels. Rudolph Diesel, who used peanut oil in his diesel engine, invented the first compression ignition engine to employ vegetable oil [1]. Biodiesel (BD), made from waste cooking oil, vegetable oils, and animal fats, is a form of alternative energy that could replace petroleum-based diesel fuel. Biodiesel greatly reduces harmful exhaust emissions and improves the performance characteristics of the diesel engine [2]. According to the definition provided by the American Society for Testing and Materials, BD is a mixture of long-chain mono alkali esters from fatty acids that are generated using renewable resources and intended for use in diesel engines. Biodiesel has the benefit, in comparison to traditional diesel fuels, of having a higher oxygen content, flash point, and fire point; all three of these characteristics contribute to the production of complete combustion. These characteristics of biodiesel decrease the exhaust gas emissions of carbon monoxide and hydrocarbons compared to diesel fuel, which

Proceedings DOI: 10.21467/proceedings.161; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-965621-8-2

results in less pollution. The fast rise in industrialization and the ever-increasing need for energy in the population are driving significant increases in the usage of fossil fuels. When energy is generated from fossil fuels, more greenhouse gases are released into the atmosphere. Because of this, many researchers are looking toward CO_2-free renewable fuels. Every nation's social and economic progress is inextricably linked to its access to affordable and reliable energy sources. As fossil fuels run out, there has been a corresponding increase in research efforts directed toward developing sustainable renewable energy alternatives. An alternative to fuels derived from petroleum is the utilization of energy sources that are based on biomass. Because of this, activities in the field of research focused on developing and implementing biofuels have become increasingly important in recent years. There is potential for substituting biodiesel for diesel in several applications [3]. Diesel engines also play an important role in transportation and agriculture. Along with advances in technology and innovation, the use of petroleum and diesel is increasing in parallel. High spending, continue depletion, and natural pollution of non-renewable energy sources has created a need for various alternative fuel sources, focusing on reducing and solving global warming. The impact of environmental toxic pollutants on human immunity is a subject of research. The impact of air pollution on human health has been extensively studied, with evidence suggesting that it can lead to various diseases and weaken the respiratory tract, skin, and organs of vision. The projected rise in population and technological advancements necessitates a surge in energy demand, which can only be met by utilizing non-renewable fossil fuels as a power source. The widespread adoption of compression ignition engines for major power conversion applications is largely attributed to the significant role played by internal combustion engines [4]. The higher oxygen content and atomization properties of biodiesel have been found to affect the chemical reaction temperature, resulting in increased levels of nitrogen oxides compared to diesel. The suitability of biodiesel from different sources for direct use in prime movers has been investigated. However, it has been found that lower ratio blends exhibit superior evaluation of emissions and investigated performance compared to pure biodiesel. The study indicates that biodiesel's high cetane number and oxygen content considerably decrease primary tailpipe emissions compared to diesel. Deposits resulting from the autoxidation of biodiesel have been found to contribute to surface wear and fuel line blockages. The researcher found that the impact of mustard oil biodiesel results in a noteworthy reduction in CO and smoke emissions. However, the shown that using this biodiesel enhances to an increase in NO_X emissions. The search for alternative vegetable oils to diesel fuel varies across countries, with preferences based on the prevailing climate and soil conditions. Soybean oil, canola, sunflower, palm, and coconut oils are being investigated as potential substitutes for diesel fuel in various regions. Specifically, soybean oil is being examined in the United States, canola and sunflower oil in Europe, palm oil in Southeast Asia, and coconut oil in the Philippines. Due to the higher demand for edible oil than domestic production, utilizing it for vehicle applications is not feasible. India's forest resources are abundant due to its tropical climate. The country has diverse trees that yield significant quantities of oilseeds. A continuous transesterification process was applied to obtain high-quality glycerine from biodiesel, using edible oil as the raw material. The user reported on the existence of four primary techniques to produce BD, namely direct use, and blending, microemulsion, pyrolysis, and transesterification. The transesterification of vegetable oils and animal fats is a widely employed process. The transesterification reaction was investigated to determine the effects of various parameters on its outcome. The molar ratio of glyceride and alcohol, catalyst type, reaction temperature, reaction time, free fatty acid content, and water content in the oil were all considered variables [5]. Pyrolysis is a thermal chemical reaction that occurs without oxygen or oxygen-containing compounds. It includes the destruction of substances through the application of thermal energy. The procedure yields three distinct components: biogas, a liquid fraction that can be condensed, and a volatile fraction that comprises a solid carbon-rich solid residue. Pyrolysis is a process that is widely recognized for its versatility in enabling the fine-tuning of various experimental variables, such as, for example, B. Optimizing the final pyrolysis temperature, heating rate, annealing time, and other relevant factors is crucial to fully realizing the potential of biochar as a fuel source and as an alternative to activated carbon and biogas for various applications. The outcome is contingent on various factors. Pomegranate peels are being investigated as a potential alternative energy source due to their low cost and abundance as an industrial biomass waste product. Ongoing research explores the feasibility of utilizing this waste material for energy production. Punica granatum, known as pomegranate, has been cultivated in the Mediterranean region since ancient times. This fruit's global production volume has reached approximately 1 million tons. According to recent research, Tunisia has emerged as a significant pomegranate producer, with an estimated output of over 60,000 tonnes. Most of this production is concentrated in the country's southern region, accounting for over 60% of the total yield. Typically, the food industry and residents both consume a lot of pomegranates. This results in the production of significant quantities of biomass waste. Numerous studies have been conducted on the chemical composition of pomegranate leaves, flowers, juice, and peel, despite the socioeconomic significance of this fruit in the region. [6]. Recent work was carried out with fuel additives, so there is an increase in the combustion and performance parameters of the base fuel. Oguntola J A *et al.* [7] focused on producing and testing biodiesel fuel from coconut oil and its blend. The research aimed to investigate the feasibility of using coconut oil as a source of biodiesel fuel and evaluate the performance of the resulting fuel blend. This study incorporates various production technique and testing of palm oil-based biodiesel fuel. These methods comprise of transesterification and analysis of fuel properties. The various type of ongoing research shows valuable insights into the feasibility of palm oil as sustainable alternative to conventional biodiesel fuels. The study examined the viability of coconut oil as a renewable energy source to produce biodiesel, intending to offer a more environmentally friendly substitute for FD. In this study, coconut oil biodiesel was synthesized via a transesterification reaction. The reaction used 100 g of coconut oil, 20.0% ethanol, and 0.8% potassium hydroxide catalyst. The reaction temperature was maintained at 65 °C for 120 minutes. B. Prasanth Kumar *et al.* [8] investigated on the performance and emissions of a CI engine driven by waste mango-seed biodiesel and its blends with fossil diesel (2019). The MSBD20 reduced exhaust pollutants and increased performance at all loads. At peak loads, mango seed 20 has the highest brake thermal efficiency. Mango seed blends also reduced NO_X and CO emissions. Natesan Kapilan *et al.* [9] experimental investigations on biodiesel engine NO_X emission reduction utilizing a unique natural additive (2021). They found that synthetic and nano-metal biodiesel additions may harm the environment; therefore, non-toxic, low-cost, biodegradable, and sustainable additives are needed to reduce NO_X emissions. Dawody and Bhatti. [10] Conducted an experiment in which they used soy oil in conjunction with mixed diesel in 2011. During this research, it was discovered that using soy oil blended with diesel in varying percentages increased the engine's specific consumption, even though the engine's efficiency was somewhat reduced due to the oil's lower heating value. W. Saadi *et al.* [11] investigated the potential of pyrolysis technologies for converting pomegranate peel wastes. The aim is to explore the feasibility of utilizing this waste material as a valuable resource by applying thermal decomposition processes. The study focuses on characterizing the pomegranate peel waste and evaluating the pyrolysis products, including biochar, bio-oil, and syngas. This research provides insights into the potential of pyrolysis technologies for the sustainable management of pomegranate peel waste. An analysis of the potential opportunities in the bioenergy industry (2019). The study analysed bio-char yield obtained from two different processes and it was found as comparable. However, the yields of bio-oil and biogas were observed to be greater in flash pyrolysis, with variations based on temperature. The study's findings indicate that biochar has potential as a fuel source. Additionally, it was observed that a decrease in flash pyrolysis temperature increased bio-oil yield. All the studies primarily focus on enhancing performance metrics while mitigating environmental impacts by reducing emission parameters.

Overall, the literature review showed that different researchers used various kinds of fuel to make BD and test its effects on diesel engines. Very few researchers used pomegranate peel to extract oil for preparing BD.

In this study, oil was extracted from used pomegranate peels using a Soxhlet apparatus. BD was made by transesterification reaction and performed on a diesel engine.

2 Materials And Methods

This study uses pomegranate peel to make pomegranate peel powder, which varies from dark purple to deep red. Pomegranate is produced annually in India, with the peak season from February to May. It can be found in several states of India, such as Maharashtra, Gujarat, Karnataka, Madhya Pradesh, etc. Maharashtra is India's central pomegranate-producing state, accounting for approximately 66% of total production.

2.1 Preparation of Peel Powder Process

The process of powder preparation follows the following steps- collection of pomegranate peel, the drying process in the presence of sunlight and grinding process. first, the pomegranate peel was collected and dried in sunlight for 12 to 14 days. The drying process of pomegranate peel was shown in figure 1, figure 2 and figure 3. Figure 1 shows the raw pomegranate peel, figure 2 shows the pomegranate peel after 12-14 days and figure 3 shows the powder form of dried pomegranate peel.

Figure 1: *Pomegranate peel*

Figure 2: *Drying process*

Figure 3: *Powder form of dried pomegranate peels*

Sunlight completely evaporates the moisture from this dried peel before using a grinder to grind the dried peels into powder.

2.2 Oil extraction by Soxhlet apparatus

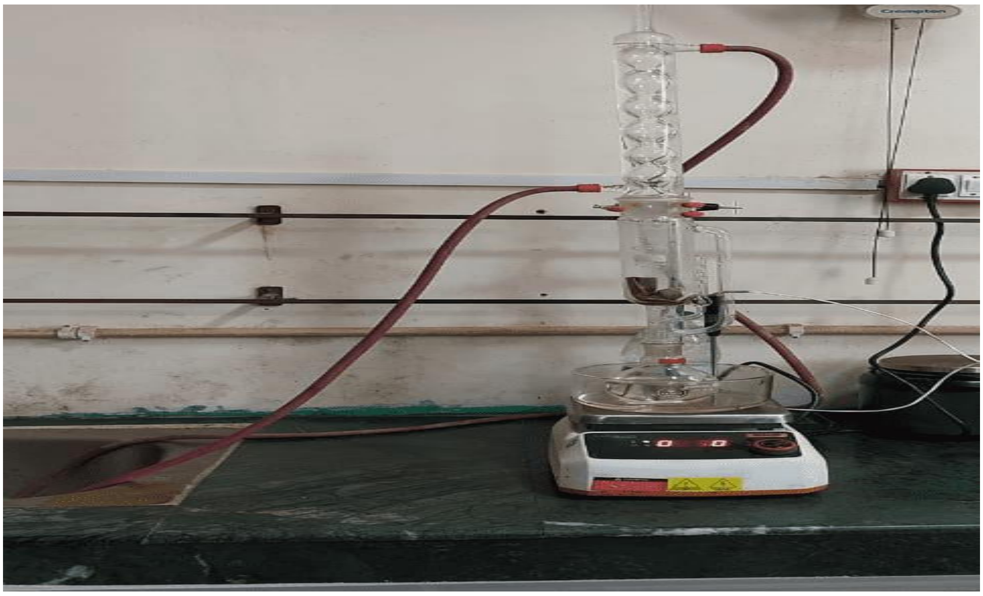

Figure 4: *Soxhlet apparatus*

The Soxhlet apparatus is used to extract the oil with the help of solvents such as n-hexane, ethanol, and acetone. The main parts of the Soxhlet apparatus are a heating mantle, round flask, extraction chamber, thimble, and condenser, as shown in the above figure 4. 100 g of the dried sample is placed in a thimble for oil extraction. The thimble is then fed into the main chamber of the Soxhlet extraction chamber. 500 ml of n-hexane solvent is filled into a round flask and kept on the heating mantle. A Soxhlet extraction chamber is placed on top of the round flask, and a condenser is placed on top of the extraction chamber. Inlet and outlet pipes are joined with the condenser, where cold water enters from the inlet, and hot water emerges from the outlet. Heat is supplied through the heating mantle to the round flask at a temperature of 69 °C, which is the boiling point of n-hexane. After a few times, it starts boiling and vaporizing; the vaporized solvent goes to the condenser, where it condenses and is converted into liquid via a vapour tube. The liquid is then passed drop by drop through the thimble, and at a certain level, it comes back along with the extracted pomegranate oil into the round flask through a syphon-tube due to the gravitational force. Due to its high boiling point, the extracted pomegranate oil is not vaporized with n-hexane; hence, the oil remains in the round flask. The same cycle occurs four to five times for the complete oil extraction from one thimble and takes approximately one hour. After that, the thimble is changed and follows the same procedure as above to extract more pomegranate oil.

2.3 Chemicals Used

Figure 5: *Methanol*

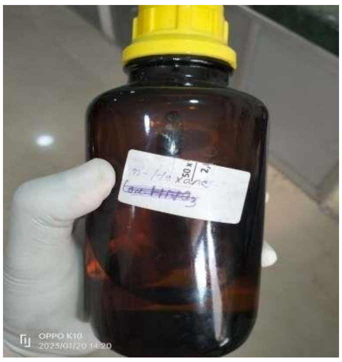

Figure 6: *n-hexane*

Figure 7: *Sodium Hydroxide*

Proceedings DOI: 10.21467/proceedings.161
ISBN: 978-81-965621-8-2

Series: AIJR Proceedings
ISSN: 2582-3922

Chemicals such as methanol n-hexane, and sodium hydroxide (NaOH) are required which are shown in figure 5, figure 6 and figure 7. n-hexane is used as a solvent for oil extraction from pomegranate peel powder. Methanol and NaOH are used during transesterification, where NaOH works as a catalyst, improving the transesterification reaction rate.

2.4 Transesterification method

Transesterification, also defined as an alcoholic reaction, is a consecutive reversible reaction between alcohol and vegetable oils in the presence of a catalyst. The transesterification process requires a chemical reaction that facilitates the conversion of the triglycerides present in oils into a form of biodiesel that can be utilized. In this method, triglycerides are changed into monoglycerides. The transesterification process produces biodiesel with a lower viscosity, which enables it to substitute petroleum-based diesel in diesel engines.

Figure 8: *Magnetic stirrer*

Figure 9: *Transesterification*

The transesterification process produces biodiesel from pomegranate peel oil, with a temperature range of 60 to 65 ℃. The research involves the reaction of pomegranate peel oil with methanol in the presence of NaOH as a catalyst. The chemical breakdown of the pomegranate peel oil molecule results in the formation of methyl ester, a component of pomegranate peel oil. The process of converting oil into ester is a crucial step in the production of biodiesel. The glycerin was separated from the main product. The glycerin sinks to the bottom during separation, and the biodiesel floats on top. Pomegranate oil biodiesel preparation through the transesterification process is used because this process gives the best result. Take 50 ml of pomegranate oil and a solvent of methanol and NaOH (catalyst). The measured NaOH and methanol are stirred until they dissolve properly, figure 8 shows the magnetic stirrer which is used to dissolve NaOH and methanol. pomegranate oil is stirred and heated to eliminate the moisture. The temperature of pomegranate oil is maintained at 60 °C. After that, the NaOH and methanol solutions are mixed in pomegranate oil, and the stirring speed ranges between 550 to 600 rpm, figure 9 shows the transesterification reaction. After that mixture, bring in a separation funnel to separate the biodiesel and glycerine. figure 10 a show the separating funnel in which upper layer shows the biodiesel and lower layer shows the glycerine. Figure 10 b shows the pure biodiesel.

$$\% \text{ of yield calculation} = \frac{\text{Total weight of biodiesel}}{\text{Total weight of oil in sample}} \times 100 \quad (1)$$

$$= \frac{41 \text{ ml}}{50 \text{ ml}} \times 100$$

$$= 82\%$$

(a)

(b)

Figure 10(a) : *Separating funnel*

Figure 10 (b) : *Biodiesel*

2.5 Properties of test fuel and its blends

The properties such as calorific value, density, flash point and fire point of diesel, blending mixture (biodiesel and pomegranate peel biodiesel) are shown in table 1.

Table 1: *Properties of diesel and blending mixture*

Properties	**Equipment name**	**Diesel**	**PPBD10**	**PPBD20**
Calorific Value (kJ/kg)	Bomb calorimeter	42600	34630	33125
Density (kg/ m^3)	Hydrometer	830	839	844
Flash Point (°C)	Pensky marten	64	74	71
Fire Point (°C)	Pensky marten	69	78	73

Two different blending ratios were developed using pomegranate peel biodiesel (PPBD) as a blending agent. The blends were mixed using magnetic stirring to ensure homogeneity, named PPBD 0 (fossil diesel 100%), PPBD 10 (10% biodiesel + 90% fossil diesel), PPBD 20 (20% biodiesel + 80% fossil diesel), and PPBD, to check their performance and emission analysis on a single cylinder, four-stroke diesel engine.

3 Experimental Setup

Performance parameters like BSFC, BTE and emission parameters like NO_X, HC, and CO with varying loads of 0 kg, 1 kg, 2 kg, 3 kg, 4 kg, and 5 kg are determined.

Proceedings DOI: 10.21467/proceedings.161
ISBN: 978-81-965621-8-2

Series: AIJR Proceedings
ISSN: 2582-3922

Figure 11: *Experimental setups*

The present study investigates the performance of a prepared test fuel, namely pomegranate peel BD and its blends, using a 4-stroke single cylinder CI engine, specifically the Kirloskar agricultural diesel engine. The study involves the utilization of fossil diesel as the primary fuel source for the engine, intending to record data for performance and emission analysis. Figure 11 shows a diagram of the experimental setup that was utilized in the study. The study used typical operational parameters, including a fuel injection pressure of 220 bar, a compression ratio of 15:1, and a diesel engine speed 1500 rpm. The load was measured in ascending order using a rope dynamometer. The prepared pomegranate peel biodiesel blends were subjected to individual testing.

3.1 Engine Specifications

For the testing of blending mixture of pomegranate peel biodiesel with diesel on 4 stroke single cylinder diesel engine was used. Table 2 shows the detailed engine specifications of diesel engine.

Table 2: *Engine specification*

Parameters	**Value**
Engine type	4-Stroke single-cylinder, CI engine
Number of cylinder and nozzle hole	1 and 3
Bore and stroke (mm)	102,110
Cubic capacity (cm^3)	898
Compression ratio	15:1
Specific fuel consumption (g/kW hrs.)	251
Cooling system	Water cooled
Dynamometer	Rope brake dynamometer
Rated output (kW)	7.45
Rated speed (rpm)	1500
Injection pressure (bar)	220

The performance parameters such as brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) are calculated as:

Brake thermal efficiency (BTE):

$$BTE = \frac{BHP}{TFC \times CV} \times 100 \quad (2)$$

Where, TFC = Total fuel consumption

CV = Calorific value in kJ/kg

Brake specific fuel consumption (BSFC):

$$BSFC = \frac{TFC}{BHP} \text{ in kg/kW-hr} \quad (3)$$

4 Results & Discussion

4.1 Performance Parameters

This paper examines the performance parameters of pomegranate peel biodiesel blends compared to fossil diesel under varying engine loading conditions. The performance in terms of brake thermal efficiency (BTE) and brake-specific fuel consumption (BSFC) is discussed as:

4.1.1 Brake Thermal Efficiency

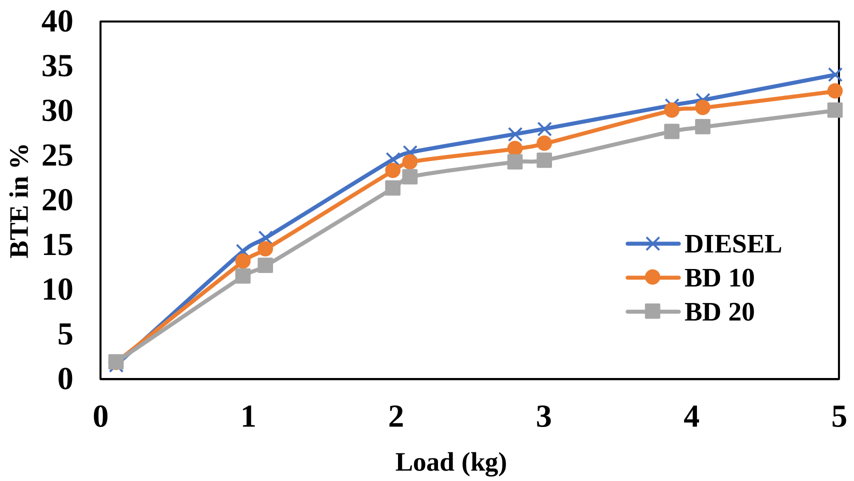

Figure 12: *Variations of BTE VS LOAD*

Figure 12 above shows BTE variations with engine load for prepared pomegranate peel biodiesel blends and conventional diesel. Brake thermal efficiency is indicated as power/heat supplied. Due to their reduced calorific value, pomegranate peel biodiesel blends have poorer braking thermal efficiency than diesel. According to the above fig, the brake thermal efficiency values of diesel, PPBD10, and PPBD20 are 34%, 31%, and 30%, respectively.

Proceedings DOI: 10.21467/proceedings.161
ISBN: 978-81-965621-8-2
Series: AIJR Proceedings
ISSN: 2582-3922

4.1.2 Brake-specific fuel consumption

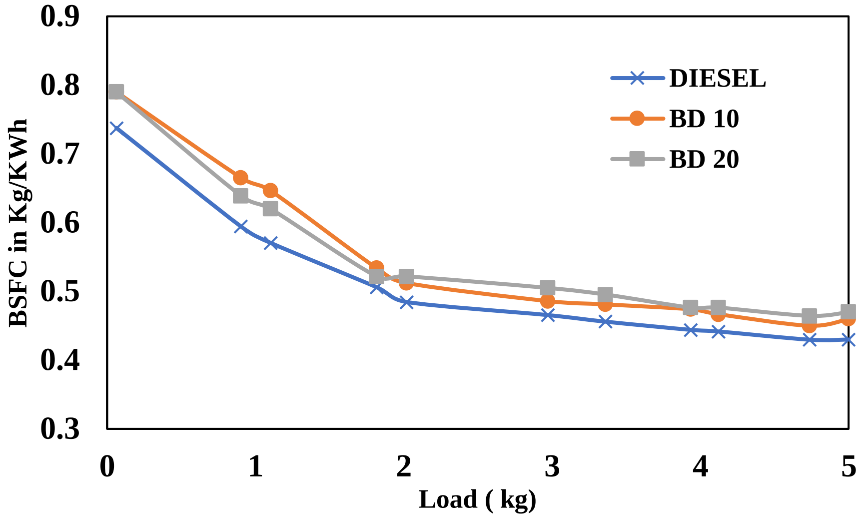

Figure 13: *Variation of BSFC with LOAD*

In the above figure 13 for diesel and prepared fuel blends, a variation in brake-specific fuel consumption (BSFC) in response to varying amounts of engine load. "Brake-specific fuel consumption" refers to the ratio of a vehicle's total fuel consumption to the power it generates. The fuel's viscosity, density, calorific values, and cetane number significantly impact brake-specific fuel consumption (BSFC) [12]. According to the above graph for diesel and blends, the BSFC fell monotonically as braking power increased. Pomegranate peel biodiesel blends, brake specific fuel consumption is higher than diesel due to the lower calorific values of pomegranate blends.

4.2 Emission Parameters

4.2.1 Carbon Monoxide Emission

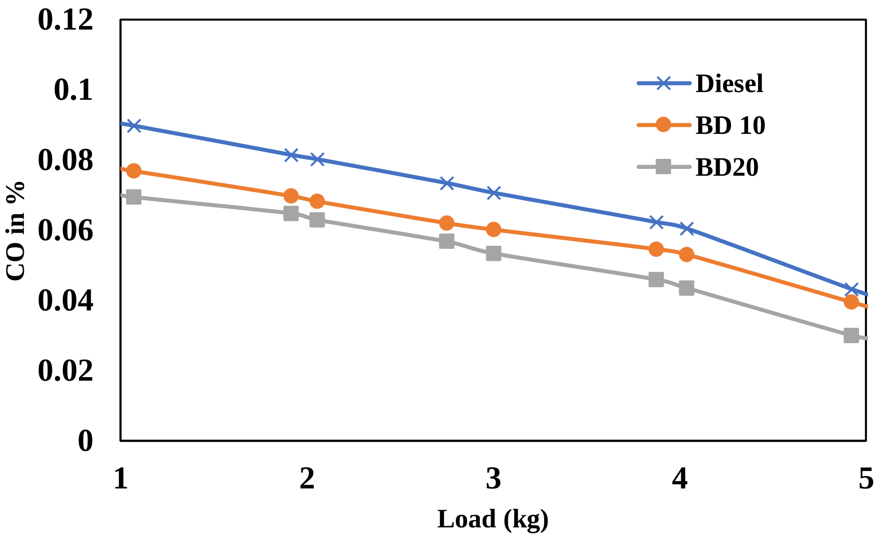

Figure 14: *CO Emission with Load*

Figure 14 shows the change in the amount of CO that occurs over a range of engine loads for both the prepared test fuel blends and diesel. Because pomegranate mixes contain more oxygen than diesel, the CO emission percentage is significantly lower for pomegranate BD blends than diesel. Many radicals are created because of the rapid release of heat during the premixed combustion phase. As a result of the high rate of heat release that occurs during the premixed phase of combustion, a greater number of radicals are produced. These radicals contribute to the combustion diffusion phase and help limit carbon monoxide (CO) emissions. According to the graph just presented, it is possible to deduce that the carbon monoxide emissions that PPOB10, PPOB20, and diesel produce at full loads are, respectively, 0.076%, 0.069%, and 0.089%.

4.2.2 Hydrocarbon Emission

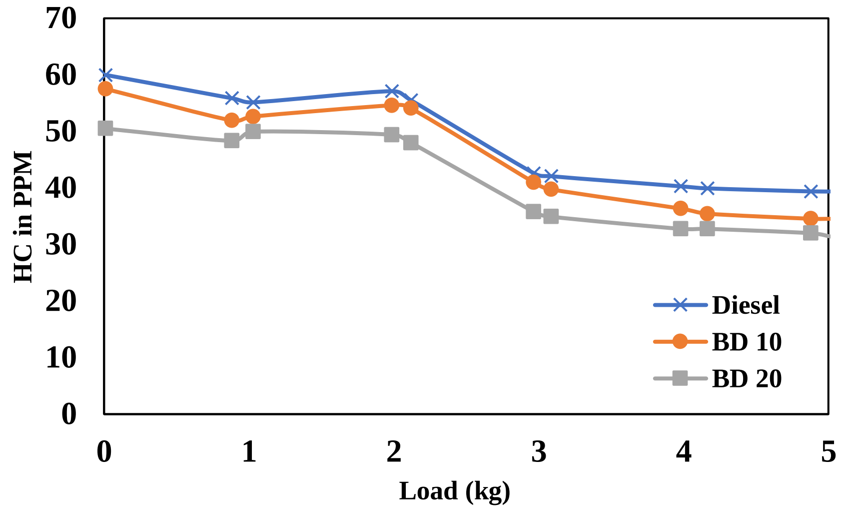

Figure: 15: *HC Emission with Load*

Figure 15 shows the variation of hydrocarbon (HC) emissions with various engine loadings for prepared pomegranate peel biodiesel test fuel blends and diesel. Unburned hydrocarbons are released from an engine's cylinder due to incomplete combustion. The increasing engine load raises hydrocarbon emissions. Because of this, pomegranate peel biodiesel blends have lower hydrocarbon (HC) emissions. In the above figure 15, it can be observed that the HC emission values for PPOB10, PPOB20, and diesel are 34.55 PPM, 31.33 PPM, and 39.38 PPM, respectively, at full loads.

4.2.3 NO_x Emission

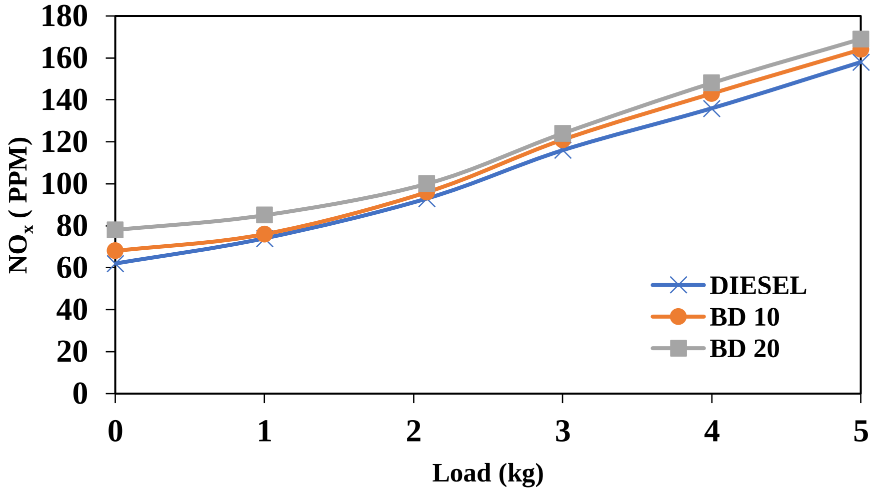

Figure 16: *NO_x emission*

The variations in nitrogen emission (NO_x) oxides for diesel and various pomegranate peel biodiesel blends are shown in figure 16. When nitrogen and oxygen gases react during combustion at high temperatures, NO_x is produced. NO_x levels increase when engine loads increase. In pomegranate peel biodiesel blends,

Proceedings DOI: 10.21467/proceedings.161
ISBN: 978-81-965621-8-2

Series: AIJR Proceedings
ISSN: 2582-3922

NO_x emission percentages are higher than in diesel due to higher oxygen content, ignition delay, and heat release. Due to this, it leads to higher NO_x emissions for pomegranate peel biodiesel blends.

5 Conclusions

Experimental work was done to analyze the performance and emission characteristics of a water-cooled CI engine fuelled with pomegranate peel biodiesel and diesel blends. The engine in question was a single-cylinder, four-stroke model. The results of the analysis led to the following conclusions.
The brake thermal efficiency (BTE) of pomegranate peel biodiesel blends is comparatively lower than that of diesel. The study investigated the brake thermal efficiency of PPBD10 and PPBD20 compared to diesel at full loads. Results indicate that PPBD10 and PPBD20 exhibit lower brake thermal efficiency, with values of 31% and 30%, respectively, compared to diesel.
The results explained that BSFC is higher than FD and lower CO emission for pomegranate peel biodiesel. The result shown that the (carbon monoxide) CO emission of PPOB10 and PPOB20 were 0.076% and 0.069%, respectively. In this paper, brake thermal efficiency of diesel engine of diesel engine at 0-5 KW loads and found that specific fuel consumption less than diesel. The results indicate that incorporating pomegranate peel into biodiesel blends reduces HC emissions compared to FD. The study measured the HC emissions of PPBD10 and PPBD20 and found them to be 34.55 PPM and 31.33 PPM, respectively. The present paper investigates the NO_X emissions in biodiesel blends containing pomegranate peel and compares them with diesel.
So, pomegranate peel biodiesel blends can be used as alternative fuels in conventional diesel engines without any significant modification in the engine.

Abbreviations:

PPBD – Pomegranate peel biodiesel

FD – Fossil diesel

BTE – Brake thermal efficiency

FCR – Fuel consumption rate

BSFC – Brake specific fuel consumption

CO – Carbon monoxide

HC – Hydrocarbon

CO_2 – Carbon dioxide

SO_2 – Sulphur dioxide

O_2 – Oxygen

NO_X – Nitrogen dioxide

6 Declarations

6.1 Competing Interests

The authors declare no conflict of interest.

6.2 Study Limitations

There are no limitations that significantly affect the research outcome.

6.3 Acknowledgements

The authors would like to thank the mechanical and chemical engineering department of MMMUT Gorakhpur for providing laboratories to conduct experiments smoothly and successfully.

6.4 Warning for Hazard

The "Effect of Waste Pomegranate Peels Biodiesel on Performance and Emission Analysis of Diesel Engine" does not involve any chemicals, procedures, or equipment with unusual hazards.

6.5 Ethical Approval

Ethical approval is not required for this study.

6.6 Informed Consent

No human or animal subjects were involved in this research; hence no informed consent was obtained.

6.7 Publisher's Note

AIJR remains neutral with regard to jurisdictional claims in institutional affiliations.

How to Cite

Yadav *et al.* (2023). Effect of Waste Pomegranate Peels Biodiesel on Performance and Emission Analysis of Diesel Engine. *AIJR Proceedings*, 50-63. https://doi.org/10.21467/proceedings.161.6

References

[1] Dueso, Cristina, Mariano Muñoz, Francisco Moreno, Jorge Arroyo, Noemí Gil-Lalaguna, Ana Bautista, Alberto Gonzalo, and José Luis Sánchez. "Performance and emissions of a diesel engine using sunflower biodiesel with a renewable antioxidant additive from bio-oil." *Fuel,* vol. 234, pp 276-285. J. Fuels. 2018. https://doi.org/10.1016/j.fuel.2018.07.013.

[2] Ahmad, Khurshid, and Prashant Saini. "Effect of butanol additive with mango seed biodiesel and diesel ternary blends on performance and emission characteristics of diesel engine." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* vol.44, no. 4, pp-9988-10005, Energy Sources A: Recovery Util. Environ. 2022. https://doi.org/10.1080/15567036.2022.2143954

[3] Kamitkar, Nitin, Basavaraju Alenahally Ningegowda, and Vallapudi Dhana Raju. "Assessment of Indian black berry biodiesel characterisation and its suitability for the diesel engine applications with oxygenated fuel additives." *International Journal of Ambient Energy* vol. 43, no. 1, pp. 7715-7726, Int. J. Ambient Energy. 2022. https://doi.org/10.1080/01430750.2022.2075930

[4] Saravanan, N., G. Nagarajan, and Sukumar Puhan. "Experimental investigation on a DI diesel engine fuelled with Madhuca Indica ester and diesel blend." *Biomass and Bioenergy*, vol.34, no. 6 pp- 838-843, Biomass Bioenergy. 2010. https://doi.org/10.1016/j.biombioe.2010.01.028

[5] Abed, K. A., Akila K. El Morsi, Mahmoud M. Sayed, A. A. El Shaib, and M. S. Gad. "Effect of waste cooking-oil biodiesel on performance and exhaust emissions of a diesel engine." *Egyptian journal of petroleum*, vol. 27, no. 4, pp. 985-989, Egypt. J. Pet. 2018. https://doi.org/10.1016/j.ejpe.2018.02.008.

[6] Gnanamoorthi, Va Vimalanath VT, and Mc Murugun. "Experimental Investigation of Performance and Emission Characteristics of Pomegranate Peel Pyrolysis Oil as Fuel in Diesel Engine." International Science and Technology Journal", vol.7, no. 6, pp-63-68. Int Sci Techno. J, 2018.

[7] Alamu, Oguntola J., Opeoluwa Dehinbo, and Adedoyin M. Sulaiman. "Production and testing of coconut oil biodiesel fuel and its blend." *Leonardo Journal of Sciences* vol.16, pp. 95-104. Leonardo J Sci.2010.

[8] Prasanth Kumar, B., K. Appa Rao, V. Dhana Raju, S. Rami Reddy, D. Mallikarjuna Rao, and J. Subba Reddy. "Experimental investigation on the performance and emission characteristics of a diesel engine powered with waste mango seed biodiesel blends." *International Journal of Ambient Energy*, vol. 43, no. 1, pp-1378-1388, Int. J. Ambient Energy. 2022. https://doi.org/10.1080/01430750.2019.1705911

[9] Natesan, Kapilan, Rana Pratap Reddy, and Abu Saleh Ahmed. "Experimental Studies on Reduction of Nox Emission of Biodiesel Fuelled Engine Using A Novel.2021 https://doi.org/10.21203/rs.3.rs-582827/v1

[10] Dawody and Bhatti "Effect of soybean oil biofuel blending on the performance and emissions of Diesel engine using diesel-rk software." *International journal of engineering science and technology*, vol. 3, no. 6, pp. 4539-4555., Int. J. Eng. Sci. Technol. 2011.

[11] Saadi, W., Sandra Rodríguez-Sánchez, B. Ruiz, S. Souissi-Najar, A. Ouederni, and E. Fuente. "Pyrolysis technologies for pomegranate (Punica granatum L.) peel wastes. Prospects in the bioenergy sector." *Renewable Energy,* vol. 136, pp 373-382. Ren. Eng.2019. https://doi.org/10.1016/j.renene.2019.01.017

[12] Kumar, Priyankesh, Devesh Kumar, Ravi Shankar, Sachin Kumar, Prashant Saini, and Narendra Kumar. "Effect of synthesized lemongrass biodiesel on the performance and emission characteristics of a CI engine." *Sustainable Energy Technologies and Assessments*, vol.57, pp. 103221.2023. https://doi.org/10.1016/j.renene.2019.01.017