Evaluation of Straight Vegetable Oil and Waste Cooking Oil in Compression Ignition Engine

Faheem Ahmed Solangi[*], Ali Murtaza Ansari[†], Saeed Ahmed Rajput[‡], Muhammad Kashif Abbasi[§], Altaf Alam Noonari[**]

Abstract

The search for sustainable and environmentally friendly energy sources has led to a great deal of research into alternative fuels for diesel engines. In order to reduce greenhouse gas emissions and noise pollution, the study intends to evaluate how well these bio-based fuels can maintain engine performance. DF100 is pure diesel; DF95WCO5 is a blend of 5% waste cooking oil; and DF95SVO5 is a blend of 5% straight vegetable oil are the three fuel mixes employed in the experimental study on a single-cylinder diesel engine. Important exhaust emissions are assessed, including sound levels and carbon monoxide (CO) and carbon dioxide (CO_2). According to the results, adding WCO and SVO to diesel fuel significantly reduces CO and CO_2 emissions; blends like DF95WCO5 and DF95SVO5 show decreases in CO and CO_2 emissions when compared to pure diesel. This drop can be partially attributed to the higher oxygen content in WCO and SVO and their greater combustion efficiency. It is also found that sound emissions from the engine operating on WCO and SVO mixes are either the same as or slightly less than those from pure diesel. The results demonstrate that CO emissions are successfully reduced by DF95SVO5 to 0.18%.

***Keywords**:* Diesel Engine; Waste Cooking Oil; Vegetable Oil; Noise Emission; Exhaust Emission.

Introduction

Diesel engines are crucial to the locomotive, agricultural, construction, and industrial sectors because of their unparalleled torque, dependability, and fuel conversion efficiency (Sharbuddin Ali & Swaminathan, 2020). The depletion of diesel fuel resources has prompted scientists to begin researching alternative fuel sources (Chowdary et al., 2019). Even though alternative fuels are more environmentally friendly,

[*]Corresponding Author: Department of Mechanical Engineering, Quaid-e-Awam University of Engineering, Science & Technology Nawabshah, Nawabshah 67480, Pakistan, faheemahmed@quest.edu.pk
[†]Department of Technology, Faculty of Engineering Science & Technology (FEST) Hamdard University, KDA Campus, Karachi 74700, Pakistan, Ali.murtaza4646@gmail.com
[‡]Department of Basic Sciences & Related Studies, The university of Larkano, Larkana 77150, Pakistan, saeedahmed@uolrk.edu.pk
[§]Department of Mechanical Engineering, Quaid-e-Awam University of Engineering, Science & Technology Nawabshah, Nawabshah 67480, Pakistan, Muhammadkashif@quest.edu.pk
[**]Department of Energy System Engineering, Balochistan University of Engineering & Technology Khuzdar, Khuzdar 89120, Pakistan, noonarialtaf@yahoo.com

studies often demonstrate that engines operate poorer when using them (De Feo et al., 2023). Fossil fuels continue to be the most widely used energy source because they are less costly than other energy sources (Kalaiselvan, 2024; Tüccar & Uludamar, 2018).

The primary function of diesel engines is to provide mechanical power, which is used in many different sectors, such as logistics and transportation, as well as by large generators to produce electricity (Debbarma et al., 2020). Diesel engine fuel is in great demand. To offset the sharply increasing demand rate, there is a strong need for research on the development of alternative fuels. For them, the most crucial and essential research is the production of inexpensive gasoline. The goal of this research is to improve the fuel's qualities and create the best, least expensive alternative fuel from leftover cooking oil (Sathish et al., 2023). Modern diesel engines' effects of combustion increase the amount of fuel used. Nevertheless, rising demand and diesel use are associated with growing price gaps, decreasing reserves, and exacerbating ecological and human problems (Dabi & Saha, 2019). As a result, diesel engines require an appropriate replacement (Wei et al., 2018; Dhanasekaran et al., 2019).

Researchers are looking for alternative fuel sources to power diesel engines used in transportation, heavy machinery, and energy generation. Recycling is crucial to achieving ecological well-being. The globe discards billions of gallons of gutter oil annually (Hribernik & Kegl, 2009; Ali & Maki 2023). However, if waste cooking oil (WCO) is not disposed of appropriately, it poses a significant environmental risk. WCO is also cost-effective because all expenses are only spent during the data collection and processing phase (Kalam et al., 2011).

Researchers have lately become interested in alcohol-based WCO reformulation since it is a low-tech, easy, and inexpensive method of reducing the viscosity of edible oils (Sharon et al., 2013; Lujaji et al., 2011; Kumar & Jaikumar, 2014). According to a search, ternary mixtures of diesel, alcohol, and used cooking oil have a density comparable to diesel, a higher cetane number, and low viscosity (Krishnamoorthy et al., 2018). Thus, creating implementation plans to save cooking oil waste is essential to guaranteeing food security. WCO should have improved physicochemical characteristics. The qualities of waste cooking oil will thus be altered by combining it with enhanced biofuel derived from tropical biodiversity, resulting in a more effective biofuel in the transportation and power production industries. Alcohol and gaseous fuels are just a few of the renewable fuels that diesel engines may run on (Damodharan et al., 2018). Researchers have looked at using these renewable fuels to improve compression ignition (CI) engine performance while meeting lower pollution standards (Elnajjar et al., 2021). Operating traditional compression engines with renewable gaseous fuels has piqued the curiosity of several academics since the turn of the century (Elnajjar et al., 2011; Koten, 2018; Tripathi et al., 2020).

The emissions of conventional petroleum diesel engines include carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen oxides (NOx). These emissions, together with air pollution and global warming, have detrimental effects on health, especially cardiovascular and pulmonary conditions. Alternative fuels, especially biofuels made from renewable resources, are becoming increasingly popular due to these issues. (Mousavi et al., 2016) has conducted research using dual fuel engines with 90%, 88%, and 83% MES and found that higher MES caused higher NOx emissions and reduced HC and CO emissions.

There has been interest in the potential for waste cooking oil (WCO) and straight vegetable oil (SVO) to lessen environmental effects. Petroleum diesel has combustion properties different from those of SVO and WCO. For instance, there are significant differences in the viscosity, energy content, and combustion properties of petroleum diesel blends, which can have an impact on noise levels, exhaust emissions, and engine performance. Repercussions like changed engine performance and fuel compatibility must be weighed against potential benefits like reduced greenhouse gas and particulate matter emissions from Straight Vegetable Oil and Waste Cooking Oil. Combining SVO and WCO with petroleum diesel, which maintains engine performance and reduces overall emissions while allowing for the partial use of renewable energy, provides a compromise. Because of the complexity of these interactions, it is necessary to thoroughly investigate the effects of different petroleum diesel blends on exhaust pollutants and engine noise.

Methodology

The experimental setup includes an eddy current dynamometer and a one-cylinder water-powered diesel engine. The engine test bed is shown in Figure 1, the measuring apparatus is listed in Table 1, and the evaluated fuel properties are shown in Table 2. Table 3 displays the engine specifications. The tests are conducted in a controlled laboratory environment with a constant load of 1 Nm and a constant speed of 1200 rpm to ensure precise measurements of exhaust emission and sound emission characteristics. Test fuels D100, D95WCO5, and D95SVO5 are selected. The mixing process is carried out carefully to ensure consistency and homogeneity among the samples.

Figure 1: Engine experimental setup.

The exhaust emission characteristics are measured using three primary instruments: the Testo 315-1 CO Measurement is used to detect CO, and a handheld digital sound meter is utilized to assess sound emission. The Testo-535 Sensor measured CO_2 using a two-channel infrared absorption technique. These instruments provided high accuracy and resolution, ensuring reliable findings under regular test conditions. As seen in the illustration Figure.2, the mixed fuel samples consist of waste cooking oil and pure vegetable oil. They are combined to investigate the effects of different fuel samples on the properties of exhaust and sound emissions.

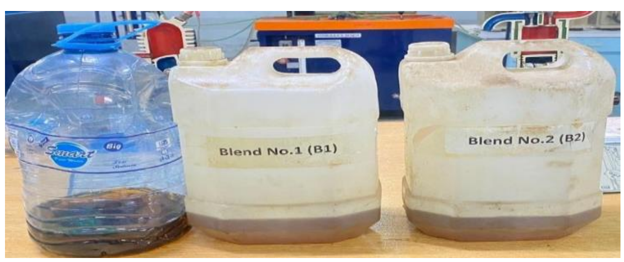

Figure 2: Blends of SVO and WCO with petroleum diesel.

Table 1: Fuel Properties.

Properties	Diesel fuel	WCO	SVO
Viscosity at 40°C(Cst)	2.28	52	32.6
Density (g/mL)	835	900	0.920
Flash Point (°C)	78	271	225
Oxygen (wt %)	0	20	11
Calorific Value (MJ/kg)	42.5	37.68	39.5

Table 2: Fuel characterization.

Properties	D100	D95WCO5	D95SVO5	Test method
Calorific valve MJ/Kg	42.5	39	41	ASTM D-240
Viscosity 40°C	2.28	2.34	3.5	ASTM D-88
Density	0.85	0.89	0.87	ASTM D-854
Flash Point °C	78	85	75	ASTM D-92
Cetane Number	50	53	54	ASTM D-4737

Table 3: Engine specification.

Model	Single-Cylinder, Horizontal, water cooled four stroke pre-combustion chamber
Bore	75mm
Stroke	80mm
Output (12 hours rating)	4.4kW/2600r/min
Displacement	0.353L
Compression Ratio	21-23
Piston mean speed	6.93 m/s
Specific fuel consumption	278.8 m/kW h
Cooling water consumption	1360 m/kW h
Injection Pressure	14.2 + 0.5 MPa
Valves clearance	Inlet valve 0.15-0.25mm
At cooled condition	Exhaust valve 0.25-0.35mm

Results and discussion

Engine Emission

The term "contamination" refers to the introduction of foreign particles into an environment that causes the physical systems or biological organisms present to become unstable, unpredictable, unhappy, or uneasy. SI and CI machines share equal accountability. Smoke, acid rain, respiratory conditions, global warming, and other health risks are all brought on by exhaust emissions. Burning non-stoichiometric materials is the primary cause of these emissions. The next section presents the emission characteristics of the experimental investigation.

Carbon Monoxide (CO)

Carbon monoxide (CO), which has no color or smell, is harmful to human health because it stops oxygen from getting into the blood. It is produced when incomplete combustion or poor fuel-air mixing results in insufficient oxygen availability (Kalaiselvan et., al, 2024; Büyükoğlu et al. 2024). For different engine working hours, Figure 3 shows the CO emissions for diesel fuel (DF100), DF95WCO5, and DF95SVO5. The results demonstrate that CO emissions are successfully reduced by DF95SVO5 to 0.18%. This shows a notable decrease in comparison to the emissions from DF100. WCO's high viscosity implied poor spray characteristics, resulting in unburned fuel. Furthermore, compared to diesel fuel, lower air/fuel ratios are required when utilizing WCO in engines (Sharon et al., 2013). DF95WCO5 has the potential to be a cleaner and more environmentally friendly option because it produces less CO when running an engine. Out of all the fuels evaluated, DF95SVO5 also had the lowest CO emissions, demonstrating the advantages of alternative fuels in reducing CO levels.

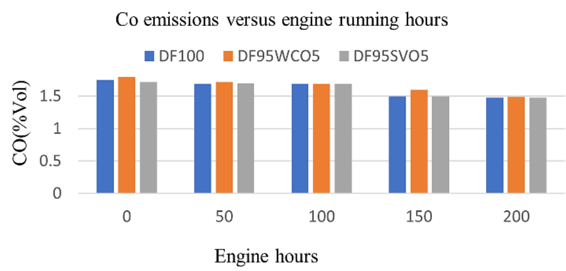

Figure 3: Carbon monoxide emissions.

Carbon Dioxide (CO_2)

This is one of the main air contaminants. Colorless, odorless, and flammable, carbon dioxide is the most common greenhouse gas in the Earth's atmosphere (Lalvani et., al, 2013). Throughout the experimental activities, Figure 4 displays the CO_2 emissions during engine working hours. It has been demonstrated that using residual cooking oil and pure vegetable oil blends instead of diesel fuel reduced CO_2 emissions. When diesel and its mixes are employed as engine test fuels, the carbon dioxide (CO_2) emissions are recorded at the same speed and throttle settings. According to an experimental study, adding waste cooking oil (DF95WCO5) to diesel fuel improved combustion characteristics and reduced CO_2 emissions. The use of pure vegetable oil as a blend DF95SVO5 further demonstrates its potential as a greener alternative to diesel, since it also resulted in decreased CO_2 emissions.

Sound Emissions

Sound emissions research findings with different diesel fuel blends show that alternative fuels like waste cooking oil (WCO) and straight vegetable oil (SVO) may be used efficiently. At many locations around the engine (Top, Front, Right, and Left), the results are systematically monitored under both zero load and one load conditions. DF95WCO5, DF95SVO5, and DF100, which is pure diesel, are the fuel mixtures that are assessed. Sound output levels are measured in decibels (dB). DF100, or the sound emission levels of pure diesel fuel, is used as a baseline for comparison. The data shows that measurements at zero load are consistent across all test locations, with a little rise to 48.2 dB at one load. It may be expected that the sound emissions of pure diesel are typically steady and predictable at different engine loads and measurement sites because these results are consistent. Adding 5% waste cooking oil (DF95WCO5) to the diesel fuel resulted in a considerable reduction in sound emissions at all measurement locations. The noise levels are often lower than those of the DF100, ranging from 46.4 dB to 47 dB at zero load. Under a single load, the sound levels ranged from 47.3 dB to 47.4 dB, which is over the baseline but still below it.

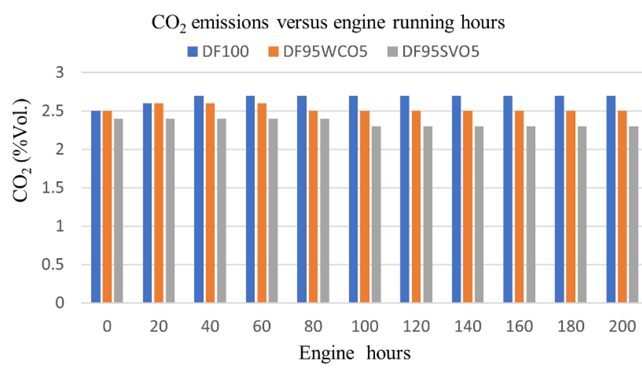

Figure 4: Carbon dioxide emissions.

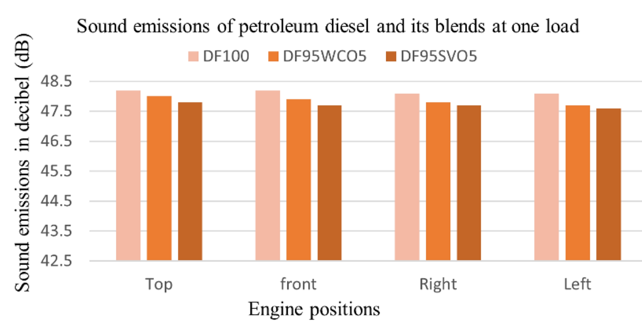

Figure 5: Sound emission at different positions.

The different combustion characteristics of WCO compared to pure diesel might be the reason for the reduced sound emissions. Engine noise may be reduced if WCO are added to the blend since it might result in a smoother combustion process. In addition to being a useful alternative fuel, this finding suggests that WCO also makes engines run more silently, which is beneficial in environments where noise pollution is a problem. A reduction in sound emissions is also shown in Figure 5 (above) when comparing the DF95SVO5 mix to DF100. At zero load, the noise levels ranged from 47 dB to 47.6 dB, whereas at one load, they are somewhat lower at 47.1 dB to 47.3 dB. These data consistently show that adding SVO to the diesel mix reduces engine noise to a level equivalent to that of the WCO blend across many testing locations. The considerably higher sound levels of DF95SVO5 compared to DF95WCO5 but still lower than DF100 suggest that SVO's special properties, namely its viscosity and combustion characteristics, may result in a different combustion noise profile than WCO. When compared to pure diesel, the overall improvement in noise levels suggests that SVO has the potential to be an alternative fuel that not only meets performance requirements but also aids in noise reduction.

Conclusion

The study found that diesel fuel combined with waste cooking oil (WCO) and straight vegetable oil (SVO) may significantly reduce emissions of carbon monoxide (CO) and carbon dioxide (CO_2). The DF95WCO5 and DF95SVO5 blends produced much lower CO emissions than the regular diesel fuel (DF100). The reason for this decline is that SVO and WCO have higher oxygen contents, which promote more thorough burning and reduce CO generation. Furthermore, the exhaust gas temperature increased somewhat as a result of using WCO and SVO mixtures. Despite its small magnitude, the increase in combustion temperature indicates that engines running on these alternative mixtures might function safely under normal conditions. Additionally, it had no negative impact on engine performance or durability. In comparison to DF100, the sound levels generated by the DF95WCO5 and DF95SVO5 mixes are either comparable to or somewhat lower. In order to reduce noise pollution, these blends may contribute to engines running more quietly because to their decreased sound emissions. Viscosity and cetane number are two examples of the physical and chemical properties of the fuel mixtures that alter combustion dynamics and account for the little difference in sound emissions.

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