Research Progress in Mechanical and Manufacturing Engineering Vol. 2 No. 2 (2021) 32-40
© Universiti Tun Hussein Onn Malaysia Publisher's Office

RPMME

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

Performance and Emissions of Vehicle Fueled with Different Blend of Euro 5 Biodiesel

Nurjihan Aimi[1], Mas Fawzi Mohd Ali[1]*

[1]Faculty of Mechanical Engineering and Manufacturing
Universiti Tun Hussein Onn, 86400, Parit Raja, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rpmme.2021.02.02.004
Received 02 Aug. 2021; Accepted 27 Nov. 2021; Available online 25 December 2021

Abstract: Biodiesel is gaining attention of the world nowadays due to the availability of sources and its renewable fuel. As an alternative fuel, biodiesel fuel has many advantages to help improve the environment. Palm Oil is one of the vegetable oils that has the potential to be used as fuel in diesel engines. The concept of different blends of palm oil biodiesel B10, B20 and, B30, 30% biodiesel, and 70% diesel in this study were used to evaluate engine performance and emission after reach 50,000 km. Dynamometer tests were conducted to obtain the performance of engines fuelled with B10, B20 and B30. The B30 fuel produces the lowest engine performance of torque and power while the B10 records the highest. The BSFC and BTE for B30 are higher compared to B20. Thus, engine emissions for B30 show lower amount of CO_2, CO, smoke opacity, and soot than B20 but has an increase in NOx and O_2 emissions. After the vehicle test using B30 fuel and after reach 50,000 km, it was found that there was no significant change in engine performance and emission.

Keywords: Biodiesel, Performance, Emissions

1. Introduction

Global energy demand continues to grow in transportation. The most practical way to meet this growing need is to use alternative fuels. The search for alternative fuels has resulted in biodiesel as it is biodegradable, renewable, and non-toxic[1]. Many biodiesel types were divided by the kind of vegetable oils such as palm oil. Biodiesel can be used alone or blended with diesel in any proportion and can be used on existing diesel engines without any further modification. A biodiesel blend of B20, 20% biodiesel, and 80% diesel has been established in Malaysia, and industries approved its usage since it does not show a significant impact on the performance. However, the usage of a higher blend is discouraged due to the possible impact that has not been fully evaluated.

Biodiesel is technically efficient and offer benefits over conventional petroleum diesel, but vegetable oil has the same high viscosity as alternative fuels than diesel. Thus, the aim of the transesterification process is to reduce the viscosity of the fuel [2-3]. Compared to diesel fuel, there are many environmental benefits associated with using higher blends of palm biodiesel. Various reports show that biodiesel reduces emissions of hydrocarbons, carbon dioxide, particulate matter, and carbon

---

*Corresponding author: fawzi@uthm.edu.my

monoxide. However, with biodiesel, a rise in the amount of NOx has been reported due to higher combustion temperatures [2,4]. The cetane number in biodiesel is higher which creates lower emissions than diesel and increases engine performance. Furthermore, vegetable oil is enticing because of its diesel-like properties, and it is derived from crops conveniently and renewably [5].

The studies by Nursal et al. found that compared to diesel fuel, overall engine performance and thermal brake efficiency have been enhanced, and the exhaust emissions and brake specific fuel consumption have been decreased [6]. Also, in biodiesel blended, CO emissions have also been shown to decrease, whereas NOx emissions have risen relative to conventional diesel fuel when using biodiesel blended fuel [7-8].

In this study, biodiesel was blended with palm oil to evaluate engine performance and emissions fuelled with different blends of Euro 5 biodiesel after 50,000 km mileage. Thus, three biodiesel types which are B10, B20 and B30, are used. The brake power (BP), brake torque (BT), brake specific fuel consumption (BSFC), and brake thermal efficiency (BTE) are the metrics for engine performance analysis. In terms of engine emission, the properties tested are carbon dioxide (CO_2), carbon monoxide (CO), oxygen (O_2), nitrogen oxides (NOx), smoke opacity, and soot of tailpipe emission.

2. Materials and Methodology

2.1 Experimental Setup

In this study, the engine tests were carried out on Toyota Hilux 2.5 L with the use of a 2KD-FTV engine model specifications stated in Table 1. A schematic diagram of the experimental engine setup is illustrated in Figure 1. The dynamometer is attached to the wheel hubs at rear wheels and is precise hydraulically controlled. Together with its built-in strength, this direct coupling system means that the dynamometer continuously controls the vehicle. The brake power and torque are evaluated by a dynamometer. The parameters of this experiment are vehicle speed of 60 km/h and 90 km/h at accelerator pedal position from 30%, 45%, 60%, 75%, and 90% using pedal adjuster. During experiment, ensure the coolant temperature from the Bosch KTS 570 diagnostic tool of the engine between 80°C and 85°C to start the test. The mass flow meter of Ono Sokki is designed to determine the engine rate of fuel consumption. It is connected through the hose from the filter to the model used is FZ-2100 Ono Sokki mass flow meters' supply and return sides. KANE AUTOplus Exhaust Gas Analyzer is used to analyse exhaust emissions in terms of CO, HC, CO_2, O_2 & NOx. It works by simply portable handheld, and analytical information will show up on the screen instantly from the smoke that has been emitted by the vehicle. The KANE AUTO600 Portable Smoke Meter is designed to measure smoke opacity emissions through a flexible probe installed into the exhaust of the vehicle. Once all parameters have been stabilized, the data of fuel flow rate, performance and emission of the engine were recorded.

Table 1: Engine Specifications

Item	Specifications
Type	Toyota
Engine	2.5-litre D-4D
Engine code	2KD-FTV
Capacity (cc)	2,494
Bore x stroke (mm)	92.0 x 93.8
Compression ratio	15.6:1
Fuel injection system	Direct injection, common rail

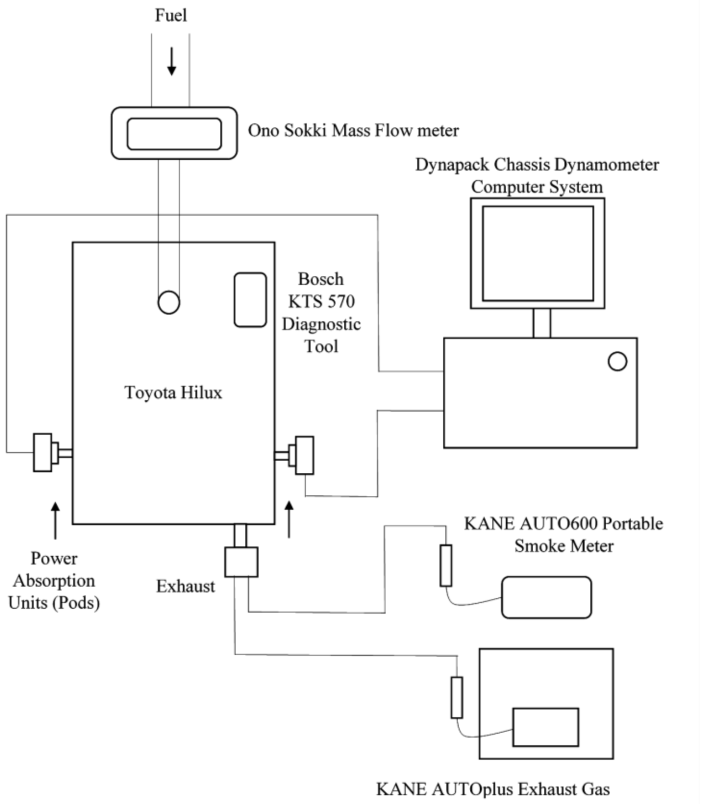

Figure 1: Schematic diagram of experimental setup

3. Results and Discussion

3.1 Comparison between Biodiesel Blends

Table 2 shows a comparison between biodiesel blends of B10, B20, and B30 for 60 km/h at 60% throttle position. From the table, the experiment performed at mileage of 50,000km found B10 produces the highest torque and power. Moreover, the highest value recorded for the amount of BSFC and BTE was B30 at the speed of 60 km/h. In terms of CO emissions, B20 produces the highest CO while B10 and B30 are the lowest. It can be observed on CO_2 and HC emissions too. As for the O_2 emission shows, using an engine fuelled by B30 emits the largest O_2 compared to the others. Therefore, as expected, B30 produces the highest NOx, but smoke opacity and soot were the opposite. The highest amount of smoke opacity and soot were by using B10 fuel.

Table 2: Comparison of biodiesel blends tested using 2.5L diesel engine

Parameters	B10	B20	B30
Torque (N.m)	232.93	232.33	221.59
Power (kW)	40.87	40.77	38.88
BSFC (g/kW.h)	216.13	216.95	218.44
BTE (%)	36.50	36.93	37.11
CO_2 (%)	6.70	7.20	6.70
CO (%)	0.01	0.05	0.01
HC (ppm)	0	8	1
O_2 (%)	8.13	8.02	8.44
NOx (ppm)	526	538	598
Opacity (%)	14	10	9
Soot (mg/m^3)	75.14	52.04	42.31

3.2 Torque and Power

Figure 2 and Figure 3 shows the graph of brake torque and power produced at various throttle positions for an engine fuelled with B30 at 60 km/h and 90 km/h. The torque values for B30 increase with the increase of throttle position and tend to stabilize after 60% throttle positions. Also, 40,000 km mileage recorded the lowest brake torque and power amount, while 10,000 the highest at 60 km/h. The torque and power decreasing with increasing biodiesel blends due to the lower calorific values of biodiesel and blend fuels.

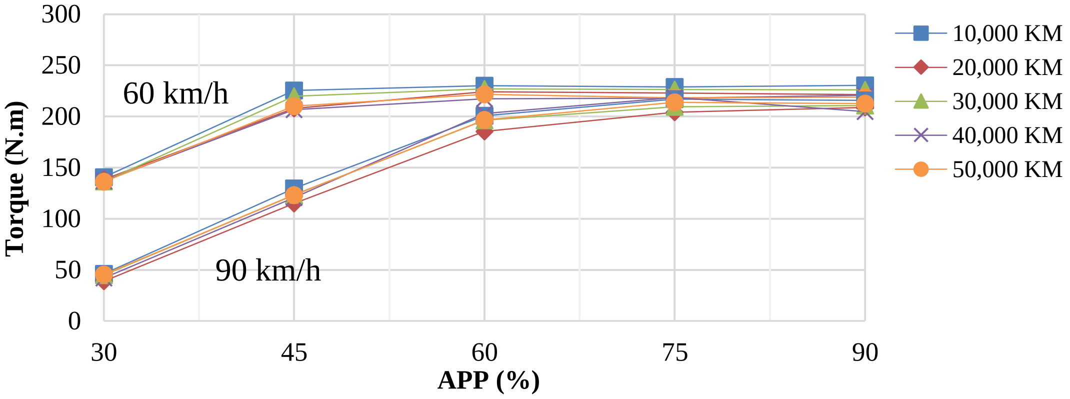

Figure 2: Brake Torque for B30 at 60 km/h and 90 km/h

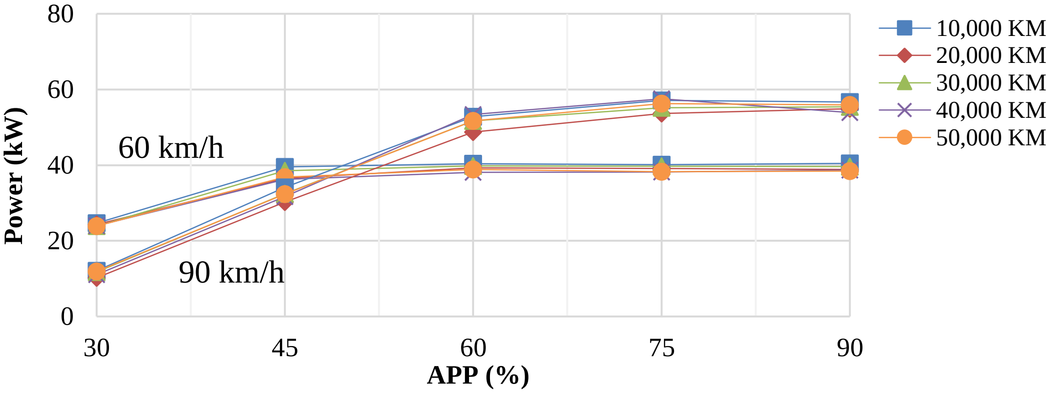

Figure 3: Brake Power for B30 at 60 km/h and 90 km/h

3.3 Brake Specific Fuel Consumption (BSFC)

BSFC is a measure of the fuel efficiency of any engine that burns fuel and produces rotational power output. It can be defined as a measurement of the engine efficiency in producing work from the supplied fuel. Figure 4 indicates minimum throttle position reveals that the BSFC of 40,000 km is lower than 20,000 km but when at full throttle position appears otherwise. Besides, if the engine speed is higher, it will result in a larger BSFC because the initial engine speed requires more fuel to overcome the mechanical friction and greater heat losses.

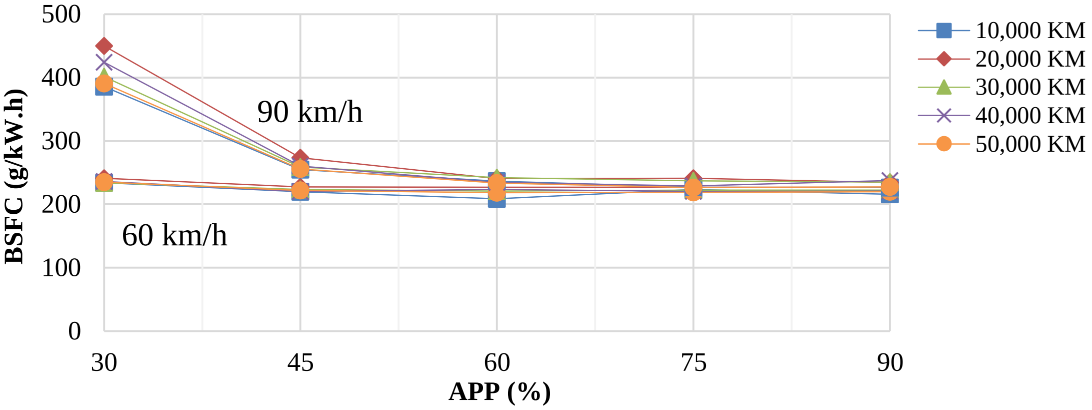

Figure 4: BSFC for B30 at 60 km/h and 90 km/h

3.4 Brake Thermal Efficiency (BTE)

BTE is the efficiency that converts the combustion of diesel fuel into effective work output, that is, the ratio of power output to energy provided by the fuel. Figure 5 reveals an increase of BTE against throttle position, while the peak BTE was at the 60% of throttle position for 10,000 km and dropped significantly. This was due to insufficient air, which caused incomplete combustion. The BTE characteristics can also be affected based on the oxygen content present in the biodiesel, and the more oxygen content in the biodiesel, the better the BTE.

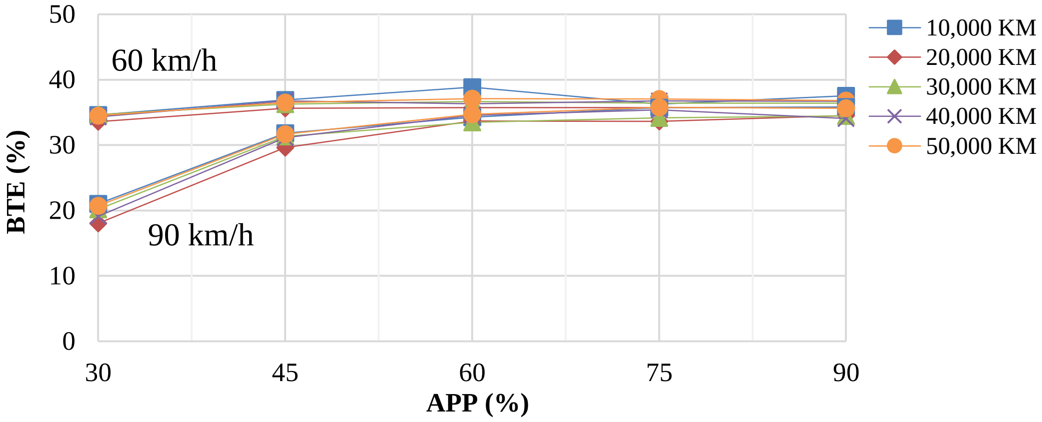

Figure 5: BTE for B30 at 60 km/h and 90 km/h

3.5 Carbon Dioxide (CO_2)

As the speed increases, the lower the reduction of CO_2 emission. This indicates that the lower speed produced CO_2 emissions by the engine will be higher. At the same time, the effect of adding biodiesel composition causes an increase in CO_2 exhaust emissions as in B30 recorded the highest CO_2 value compared to B10 and B20. Hence, CO_2 emissions will increase along the throttle position, but it can be observed for each blend of biodiesel where from 10,000 km to 50,000 km mileage shows a decrease trend.

3.6 Carbon Monoxide (CO)

CO is a toxic product produced by the combustion of all hydrocarbons, which can be diminished by increased oxygenated properties, including biodiesel. Figure 6 shows CO emission for B30 are limit to 0.05% throughout the mileage. Complete fuel oxidation leads to complete combustion, contributing to decreased emissions of CO. In general, CO levels begin to drop as biodiesel increases in the fuel blends. Biodiesel is a naturally oxygenated fuel, and the additional oxygen molecules found in the fuel help achieve better combustion resulting in lower CO emissions [9]. This is also due to the presence of oxygen in biodiesel which oxidizes CO to form CO_2.

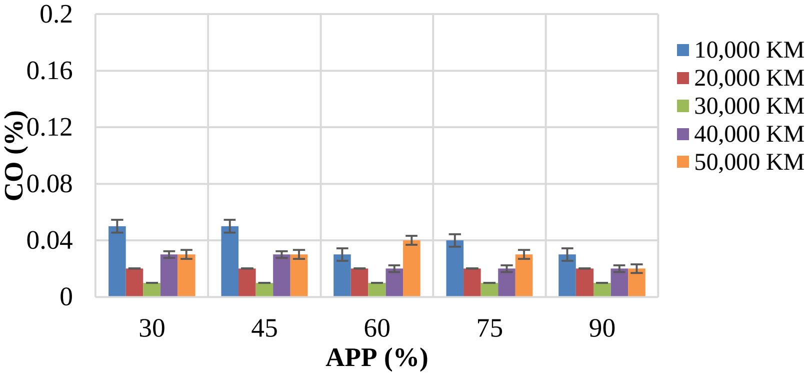

Figure 6: CO for B30 at 90 km/h

3.7 Oxygen (O_2)

Figure 7 show that the oxygen produced increases during reaching 50,000 km, but it decreases as the throttle position increases. Besides, the speed of 90 km/h for 50,000 km indicates the highest value of oxygen emission at the 30% throttle position. As the mileage increases, the higher the oxygen produced. Besides, B30 has the highest oxygen emission due to the biodiesel content.

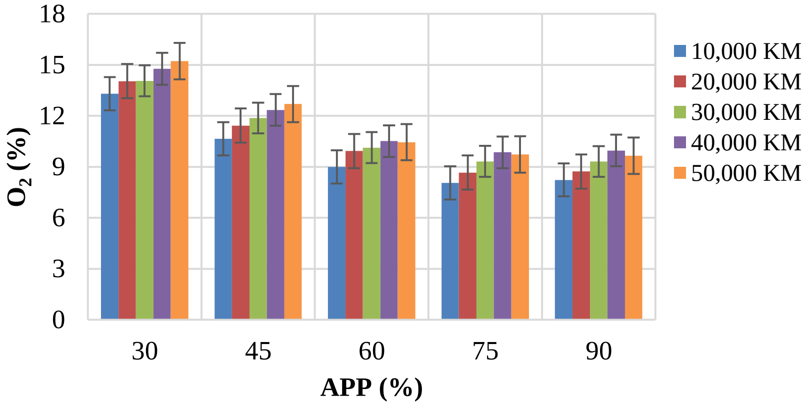

Figure 7: O_2 for B30 at 90 km/h

3.8 Nitrogen Oxides

NOx is a chemical compound of oxygen and nitrogen that is formed by reacting with each other during combustion at high temperatures. Figure 8 shows the mileage of 50,000 km has the lowest NOx emission as it decreases throughout the mileage but increase along the throttle positions. The NOx formation takes place mainly due oxygen concentration and peak combustion temperature. Most of the studies found that a higher proportion of biodiesel attributes to the increase in NOx emission due to higher oxygenated nature content in biodiesel fuel. Thus, greater fuel combustion oxidation will produce a higher amount of NOx emission using biodiesel [9].

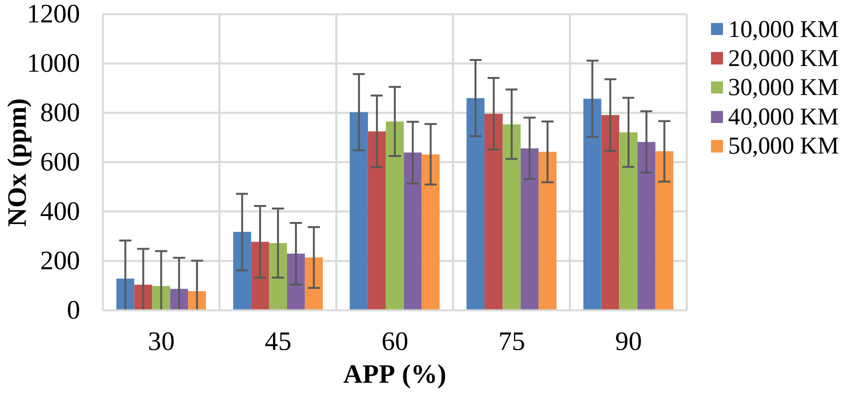

Figure 8: NOx for B30 at 90 km/h

3.9 Smoke Opacity

Figure 9 show the amount of smoke opacity against different throttle positions fuelled with B30, the mileage of 10,000 km indicates the lowest smoke opacity but there is significant gap of 50,000 km throughout throttle positions. Smoke opacity are also influenced by other parameters such as lack of oxygen, air-fuel mixing, fuel injection timing, and fuel atomization. Most of the full throttle positions has higher smoke due to the rich fuel region and oxygen inadequacy locally inside the combustion chamber. This can be attributed to the presence of oxygen and decreased carbon in the biodiesel that promotes complete combustion of the fuel during the stage of diffusion combustion [10].

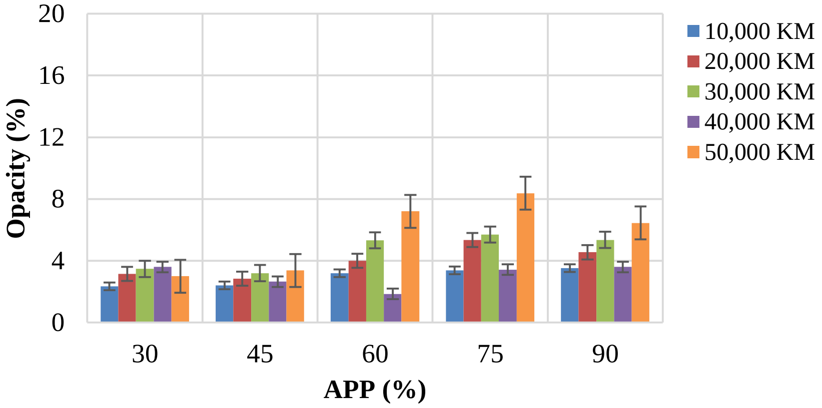

Figure 9: Smoke Opacity for B30 at 90 km/h

3.10 Soot Calculation

Soot is a black substance formed and a product of incomplete combustion. Soot has a sticky texture that tends to stick to exhaust pipes where the combustion occurs. The soot concentration can be calculated from the empirical correlation equation. By this empirical correlation method [11], it is possible to obtain the soot concentration values in (mg/m^3).

$$Soot\ (mg/m^3) = \frac{1}{0.405} 4.95.FSN.e^{(0.38.FSN)} \qquad \text{Eq.1}$$

In this study, the soot formed rises when the throttle position increases but decreases as the speed increases. At 90 km/h, at most throttle positions showing 50,000 km mileage produces the highest soot while 30,000 km is the lowest. The rise in soot formation at mileage 10,000 km to 30,000 km is consistent throughout the throttle position. Higher blend of biodiesel reduces the formation of soot.

4. Conclusion

Through the experiment of three biodiesel blend fuels of B10, B20, and B30, it can be concluded that:

i. The B30 fuel produces the lowest engine performance of torque and power while the B10 records the highest. The BSFC and BTE for B30 are higher compared to B20. Thus, engine emissions for B30 show lower amount of CO_2, CO, smoke opacity, and soot than B20 but has an increase in NOx and O_2 emissions.
ii. After the vehicle test using B30 fuel and reaching 50,000 km, it was found that there was no significant change in engine performance and emission.

Acknowledgement

The authors would like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] E. Buyukkaya, “Effects of biodiesel on a di diesel engine performance, emission and combustion characteristics,” *Fuel*, vol. 89, no. 10, pp. 3099–3105, 2010.

[2] K. Rajan, V. Sujith, M. Ganesan, M. Peer Haroon, S. D. Mathivanan, and R. Elumalai, “Performance and emissions characteristics of DI diesel engine using biodiesel blend with different injection pressures,” *Mater. Today Proc.*, no. xxxx, 2020.

[3] A. Demirbas, “Biodiesel production via non-catalytic SCF method and biodiesel fuel characteristics,” *Energy Convers. Manag.*, vol. 47, no. 15–16, pp. 2271–2282, 2006.

[4] S. Radhakrishnan, Y. Devarajan, A. Mahalingam, and B. Nagappan, “Emissions analysis on diesel engine fueled with palm oil biodiesel and pentanol blends,” *J. Oil Palm Res.*, vol. 29, no. 3, pp. 380–386, 2017.

[5] A. S. Ramadhas, C. Muraleedharan, and S. Jayaraj, “Performance and emission evaluation of a diesel engine fueled with methyl esters of rubber seed oil,” *Renew. Energy*, vol. 30, no. 12, pp. 1789–1800, 2005.

[6] K. A. Zahan and M. Kano, “Biodiesel production from palm oil, its by-products, and mill effluent: A review,” *Energies*, vol. 11, no. 8, pp. 1–25, 2018.

[7] S. H. Pourhoseini, M. Namvar-Mahboub, E. Hosseini, and A. Alimoradi, “A comparative exploration of thermal, radiative and pollutant emission characteristics of oil burner flame using palm oil biodiesel-diesel blend fuel and diesel fuel,” *Energy*, no.

xxxx, p. 119338, 2020.

[8] N. Anbazhaghan, A. Karthikeyan, J. Jayaprabakar, and A. Prabhu, “Evaluation on the consequence of cerium oxide nanoparticle additive in biomass derived fuel blended with diesel for CI engine operation,” *Int. J. Ambient Energy*, vol. 0, no. 0, pp. 1–23, 2020.

[9] B. Ashok and K. Nanthagopal, *Eco friendly biofuels for CI engine applications*. Elsevier Ltd., 2019.

[10] J. Agudelo, P. Benjumea, and A. P. Villegas, “Evaluation of nitrogen oxide emissions and smoke opacity in a HSDI diesel engine fuelled with palm oil biodiesel,” *Rev. Fac. Ing.*, no. 51, pp. 62–71, 2010.

[11] R. Viskup, “Comparison of different techniques for measurement of soot and PM emission from Diesel engine,” *CEUR Workshop Proc.*, vol. 865, pp. 1–19, 2012.