

EFFECT OF B20 AND B30 PALM OIL BIODIESEL ON PERFORMANCE AND EXHAUST EMISSION OF A DIESEL



BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (MAINTENANCE TECHNOLOGY) WITH HONOURS



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Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

EFFECT OF B20 AND B30 PALM OIL BIODIESEL ON PERFORMANCE AND EXHAUST EMISSION OF A DIESEL ENGINE

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DECLARATION

I declare that this thesis research project entitled "Effect of B20 and B30 palm-oil biodiesel on performance and exhaust emissions of a diesel engine" is the result of my own research except as cited in the references. The research project has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.



DEDICATION

This report is dedicated to my beloved family in particular, for their endless love, support and encouragement. To my supervisor DR. MOHD TAUFIK BIN TAIB who has guided me along the way to finish this project. Thank you for all your support, and give me strength untill this project is finished.



ABSTRACT

Most palm oil manufacturers, such as Indonesia and Malaysia (which contribute 80-85% of global capacity), have substantially invested in developing multiple techniques to convert palm oil, into biodiesel. Palm biodiesel output has also grown in comparison to petro-diesel. More appealing since, based on present practices in the Malaysian palm oil business, it has the potential to reduce GHG emissions by 50-70%. Differences of various biodiesel feedstock such as palm oil will generate differences in engine performance and exhaust emissions. The purpose of this study is to clarify the exhaust gas emission and engine performance produced from B20 and B30 palm oil biodiesel-diesel blends fuel in a fuel injection single-cylinder diesel engine by 3 different loads. The transesterificationprocess has been used to produce palm oil biodiesel-diesel blend fuel. The engine being coupled to an engine dynamometer to measure the engine performance parameters and a gas analyzer to measure the exhaust emissions from the engine. An engine run has been done by using D100, B20 and B30 to inspect the condition of the engine and to evaluate the data of engine performances and exhaust emissions. The result indicates that B20 and B30 biodiesel fuel was the optimum blend that had improved the engine performances and reduced the exhaust emissions without making any modifications to the direct-injection diesel engine. B20 biodiesel produced highest horsepower and torque even it consumed highest volume of fuel to travel. Other than that, B30 biodiesel emitted the lowest exhaust emissions except for Nitogen Oxide and Carbon Dioxide. Biodiesel fuel can be clarified as an effective solution to reduce greenhouse effect that produced from burning of fossil fuel.

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ABSTRAK

Kebanyakan pengeluar minyak sawit, seperti Indonesia dan Malaysia (yang menyumbang 80-85% daripada kapasiti global), telah banyak melabur dalam membangunkan pelbagai teknik untuk menukar minyak sawit, kepada biodiesel. Pengeluaran biodiesel sawit juga telah berkembang berbanding petro-diesel. Lebih menarik kerana, berdasarkan amalan semasa dalam perniagaan minyak sawit Malaysia, ia berpotensi untuk mengurangkan pelepasan GHG sebanyak 50-70%. Perbezaan pelbagai bahan mentah biodiesel seperti minyak sawit akan menghasilkan perbezaan dalam prestasi enjin dan pelepasan ekzos. Tujuan kajian ini adalah untuk menjelaskan pelepasan gas ekzos dan prestasi enjin yang dihasilkan daripada biodiesel-diesel minyak sawit B20 dan B30 campuran bahan api dalam enjin diesel satu silinder suntikan bahan api dengan 3 beban berbeza. Proses transesterifikasi telah digunakan untuk menghasilkan bahan api campuran biodiesel-diesel minyak sawit. Enjin digandingkan dengan dinamometer enjin untuk mengukur parameter prestasi enjin dan penganalisis gas untuk mengukur pelepasan ekzos daripada enjin. Pengoperasian enjin telah dilakukan dengan menggunakan D100, B20 dan B30 untuk memeriksa keadaan enjin dan menilai data prestasi enjin dan pelepasan ekzos. Hasilnya menunjukkan bahawa bahan api biodiesel B20 dan B30 adalah campuran optimum yang telah meningkatkan prestasi enjin dan mengurangkan pelepasan ekzos tanpa membuat sebarang pengubahsuaian pada enjin diesel suntikan terus. Biodiesel B20 menghasilkan kuasa kuda dan daya kilas tertinggi walaupun ia menggunakan isipadu bahan api tertinggi untuk bergerak. Selain itu, biodiesel B30 mengeluarkan pelepasan ekzos terendah kecuali Nitogen Oxide dan Karbon Dioksida. Bahan api biodiesel boleh dijelaskan sebagai penyelesaian yang berkesan untuk mengurangkan kesan rumah hijau yang dihasilkan daripada pembakaran bahan api fosil.

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LIST OF SYMBOLS AND ABBREVIATIONS

CO_2	-	Carbon dioxide
Co	-	Carbon monoxide
HC	-	Hydrocarbon
NOx	-	Nitrogen oxides
<i>D</i> ₂	-	Pure diesel
B20	-	20 percent palm oil biodiesel, 80 percent pure diesel
B30	-	30 percent palm oil biodiesel, 70 percent pure diesel
WCO	-	Waste cooking-oil
PO	14	Palm oil
	Solut TENING	UTeM

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CHAPTER 1

INTRODUCTION

1.1 Background

Due to the expensive cost of raw vegetable oils, biodiesel was created from non-edible vegetable oils, quickly becoming an environmentally benign alternative to diesel. The research goal was to identify suitable alternatives to petroleum oil, and biodiesel is today one of the finest options (Abed et al., 2018).

Biodiesel usage and studies on biodiesel-diesel fuel blends have been conducted to solve the problem of fossil fuel depletion and its environmental effect. Biodiesel is a fuel made by transesterifying animal fats or vegetable oil. (Gad et al., 2018). Due to the geographic issue, each area now prefers to use various sources, such as soybean oil in the US, Brazil, and Argentina, rapeseed oil in the European Union, and palm oil in most Asian countries. Several studies have shown that palm oil as a main raw material is economically viable. In the EU, for example, Malaysian palm biodiesel is still quite inexpensive. Meanwhile, other research has found that Malaysian palm oil can compete with the price of Middle Eastern oil crops cultivated domestically (Zahan & Kano, 2018).

Although palm oil is native to West Africa, it has been cultivated during the late twentieth century in Southeast Asia. During the middle of the 15th century, European explorers to West Africa relied on palm oil as a food supply. Palm oil was in massive demand for candle making and machine lubrication during the 18th century's British Industrial Revolution. (Zahan & Kano, 2018).

Most palm oil manufacturers, such as Indonesia and Malaysia (which contribute 80– 85% of global capacity), have substantially invested in developing multiple techniques to convert palm oil, by-products, and mill effluent into biodiesel. Since the 1980s, Malaysia's Malaysian Palm Oil Board (MPOB) has been at the forefront of palm-biodiesel research and development. The MPOB has accomplished its goal. Many techniques for producing methyl esters for biodiesel from crude palm oil (CPO) and its by-products have been developed. Palmbiodiesel output has also grown in comparison to petro-diesel. More appealing since, based on present practices in the Malaysian palm oil business, it has the potential to reduce GHG emissions by 50–70%.(Zahan & Kano, 2018).

Due to an increase in oil palm farms in Indonesia, the production of palm oil biodiesel is in doubt, prompting concerns about the environmental effect.. Land conversion to oil palm plantations has additional environmental effects, such as greenhouse gas (GHG) emissions from changes in soil carbon stocks and biomass, forest fires, air pollution emissions, biodiversity losses and animal, plant, and species losses in forest ecosystems. As a consequence, a life cycle assessment (LCA) is needed to assess the environmental impact of palm oil biodiesel production. Most palm oil biodiesel LCA studies concentrate on just one factor: greenhouse gas emissions. When it comes to palm oil production, one company conducted life cycle assessments (LCAs) that included global warming, ozone depletion, acidification, eutrophication and photochemical smog, as well as land use, biodiversity and land change. However, study participants were restricted to the mid-level, and results were evaluated at the endpoint level alone (Wahyono et al., 2020).

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1.2 Problem Statement

As the price of crude oil grows day by day, more people are converting to biodiesel to save money and lessen their dependency on fossil fuels. (Nayak et al., 2022). The combustion process happened in the chamber for biodiesel-diesel blends has produced torque to the engine and smoke through the exhaust system. The combustion process causes a number of issues.:

- Differences of various biodiesel feedstock used affect the characterization of biodiesel.
- Palm oil as biodiesel feedstock will generate differences in engine performance
- Palm oil as biodiesel feedstock will generate different exhaust emissions by the gas analyser

As a result, the goal of this research is to demonstrate and clarify that biodiesel is a compatible alternatives of diesel derived from fossil fuel.

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1.3 Objective

The purpose of this study is to:

- 1. Produced biodiesel using the transesterification process
- 2. Analyse the diesel engine performance of B20 and B30 biodiesel
- 3. To investigate the exhaust emissions of B20 and B30 biodiesel

1.4 Scope of Research

- 1. Biodiesel manufacturing using palm oil as a feedstock
- 2. Engine performance test, horse power, torque and brake specific fuel consumption.

3. Exhaust emission, CO_2 , CO, HC, and NO_x by gas analyzer

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents how palm oil (PO) was used as a biodiesel feedstock. Fuel properties of biodiesel, various feedstocks, and the applications of their compression ignition (CI) engines are summarised to choose the best various type of biodiesels blending feedstock. In this study, two biodiesel blends (B20 and B30) were utilised to measure engine performance such as brake power (BP), torque (BT), brake specific fuel consumption (BSFC), and brake thermal efficiency (BTE). In addition, emission tests on diesel-biodiesel blends (B20 and B30) were performed to evaluate the result of each blends on the engine exhaust emissions when using biodiesel.



2.2 Feedstock for biodiesel production.

Biodiesel is considered as one of the possible alternate sources of renewable energy that can be found in a variety of forms in nearly every country (Verma et al., 2021). Biodiesel is easy to use, biodegradable, nontoxic, and virtually sulphur and aromatic-free (Navak et al., 2022). Vegetable oil, waste animal fats, waste cooking oil, and palm oil are the most commonly used feedstock sources found in the literature. Biodiesel is classified into three generations depends on the kind of feedstock. An evaluation of the potential for use as a fossil fuel alternative for several generations of biodiesel and their feedstocks will be presented in this section. Biodiesel's first generation was produced from sugarcane, food crops, and vegetable oil among other sources. Many researchers have used edible oilseeds as a raw material for biodiesel manufacturing, while wheat and sugar go together frequently used as a feedstock for ethanol production. Even though biodiesel of the first generation is primarily made from food crops, rising demand for biofuels as a result of which, the number of crops diverted from the food market, resulting in a rise in global food prices in recent years. On the other hand, organic waste, non-edible seeds, timber, waste food crops, and other non-edible materials are being used to make second-generation biofuel. They are not in competition with food crops and do not require clearing land; these are being considered as a possible substitute for conventional edible food crops. Finally, algae is the principal source of third-generation biofuel. Alternative generating feedstock must be selected, which in most cases is based on the region's domestic birthplace. Feedstocks for biodiesel and the parameters of their blends will affect the overall performance, combustion, and emission characteristics of CI engines in some way. CI engine performance was unaffected by the first, second, or third generation biodiesel-diesel mixes, and the exhaust gas emissions from these engines were less dangerous than those from diesel fuel, according to the research findings. (Verma et al., 2021).

2.2.1 Waste cooking oils

Waste cooking oil has a lower utilisation rate than first-generation feedstocks, making it a better biodiesel production feedstock. WCO is also a more cost-effective feedstock than jatropha, karanja, mahua, algae, and other second- and third-generation feedstocks. Because of the frying process, WCO has distinct physicochemical properties than parent vegetable oils. In the process of oxidation and hydrolysis, the cooking process alters physicochemical qualities.. These reactions raise the moisture and free fatty acids of the WCO in comparison to raw oil, resulting in soap creation in the biodiesel synthesis process. Engine wear is also caused by WCO with a high FFA level (Singh et al., 2021a). So the Mineral acids were used to treat raw WCO (Sulfuric Acid (HSO4), Hydrochloric Acid (HCl), and Phosphoric Acid (H3PO4)) in an esterification process to reduce its free fatty acid (FFA) concentration, which determines the acid value (AV). The oil was treated in two phases with H2SO4 to minimise the FFA in the WCO. AV was lowered from 3.9 to 1.45 mg KOH/g in the first step and then to 0.34 mg KOH/g in the second. WCO was then transformed into biodiesel via a transesterification method (Razzaq et al., 2020). The future will require the use of waste oil created by various food processing businesses. The majority of waste oils come from edible oils that have been fried or cooked. Figure 2.1 depicts the percentage contribution of various oils used in the manufacturing of biodiesel. It is possible that the cost of making biodiesel might be reduced, since feedstock expenses account for around 70-80 percent of the total production costs. If waste cooking oil (WCO) is utilised as a feedstock, 60–70% can be saved (Singh et al., 2021a). TEKNIKAL MALAYSIA MELAKA UNIVERSITI



Figure 2.1 Different oils' percentage participation in biodiesel production

(Singh et al., 2021a).

2.2.2 Inedible vegetable oil

There are two types of vegetable oil: edible and non-edible. Non-edible vegetable oils, which cannot be used for cooking because of health concerns, have a lot of potential as an alternative fuel. Researchers have found that India has a large number of plants that are not edible, such as karanja, mahua, neem, jatropha, and argemone Mexicana (Arya et al., 2022), Pongamia oil, Jojoba oil, Cottonseed oil, Linseed oil, Sea mango, Poon oil, and Polanga oil (Che Mat et al., 2018), because of soil and weather conditions. The use of these mentioned feedstock has resulted in most biodiesel is now made from edible vegetable oil, raising concerns about biodiesel feedstock potentially competing with food supplies in the future. As a result, there has been a lot of research on using non-edible oils as a biodiesel feedstock. Table 2.1 depicts a variety of common edible and non-edible vegetable oils (Che Mat et al., 2018).

Table 2.1 Vegetable oil examples, edible and non-edible (Che Mat et al., 2018).

Edible oil	Non-edible oil
Sunflower oil, Corn oil, Soybean oil,	Jatropha oil, Pongamia oil, Neem oil,
oil, Coconut oil, Olive oil, Peanut	Mahua oil, Sea mango, Poon oil,
oil, Sesame-seed oil	Polanga oil-

2.2.3 Palm Oil

Biodiesel can be produced most efficiently from palm oil because of its high concentration of palmitic and oleic acids. Furthermore, palm oil has major benefits as a result of the high oil content at a low market price (see Table 2.2), abundant resources and strong capability for production accounting for one-third of global vegetable oil production and requiring a little planting area compared to other oil crops. Furthermore, unlike other oil sources, palm oil is a year-round crop with consistent output (Zahan & Kano, 2018).

Table 2.2 Price and oil content of various raw materials (Zahan & Kano, 2018)

Type of Oils	Estimated Oil Content (kg oil/ha) [98,99]	Price (USD/ton) as May 2018 [106]
Palm oil	5000	660.00
Soybean	375	793.00
Rapeseed	1000	812.00
Coconut	2670-3310	1029.00
Sunflower	SLAYSIA 800	782.00
Peanut	890	1316.00

For example, most of the manufacturers of palm oil, Indonesia and Malaysia (which supply 80–85 percent of worldwide capacity) has substantially invested in developing several ways for converting palm oil, by-products, and mill effluent into biodiesel (Zahan & Kano, 2018).

Several research comparing palm oil biodiesel productions to various types of raw materials have been conducted. Table 2.3 shows that biodiesel made from palm oil has better qualities than other types of biodiesels, especially in terms of cetane number and iodine value. Higher cetane numbers offer substantial benefits, particularly in terms of clean emissions and engine performance. The high cetane number of palm biodiesel is critical to guarantee that biodiesel-fueled engines run smoothly and quietly (Zahan & Kano, 2018).

Table 2.3 Biodiesel manufactured from various source materials has the following main fuel-related features (Zahan & Kano, 2018)

Type of Biodiesel	Kinematic Viscosity (40 °C; mm ² /s)	Iodine Value	Cetane Number	Saponification Number	Higher Heating Value
Petro-diesel	2.5-5.7	_*_	45-55	_*	42-44.3
Palm oil	4.42-4.76	35-61	59.9-62.8	186-209	37.2-39.91
Soybean	4.08-4.42	117-143	37-52	201	37.3-39.66
Rapeseed	4.59-5.83	94-120	37.6-56	-*	37.3-39.9
Čorn	3.39-4.36	103-140	55.4-59	202	39.87-41.14
Sunflower	4.38-4.90	110-143	45-51	200	37.5-39.95
Peanut	4.42-5.25	67.45	54	200	39.7
Cotton seed	4.0-9.6	90-119	41.2-59.5	204	37.5-41.68
Jatropha curcas	3.7-5.8	92-112	46-55	177-189	42.67
Fungi	4.52-4.69	54.81-91.50	56.22-61.24	190-217	39.63-40.49
Yeast	3.6-6.44	37.8-65.7	50.8-59.0	168.5-190.81	36.77-41.25
Tallow	-*	126	59	218-235	-*

* Not specified.

In comparison to petrol-diesel, their research indicated that palm-biodiesel increased overall engine performance improved minor reduction in thermal brake efficiency, and reduced emissions from brakes. In addition, the study found that palm-biodiesel reduced CO, CO₂, and HC while JCO-biodiesel caused a little increase in CO₂, NOx, and HC (Zahan & Kano, 2018).

2.3 Transesterification of triglycerides

The catalyst loading influence on the conversion of triglycerides to monoglycerides was examined in this study. Because the amount of WCO was set at 25 ml, the experiment was carried out with different amounts of catalyst. At 7g catalyst, the curve indicates a high yield of around 88 percent. It was discovered that increasing the amount from 7g had no effect on triglyceride conversion (Kori et al., 2021). Transesterification is a well-known process for converting any organic feedstock into biodiesel. Such as using cooking oil by lowering the molecule's mass and viscosity of the raw oil. In the presence of powerful catalysts, oil reacts with alcohol to create alkyl ester (biodiesel) and glycerol as a by-product of the transesterification process. Ethanol and methanol are the most regularly utilised alcohols (Verma et al., 2021). If the transesterification is done with methanol, the FAME is produced. Figure 2.2 shows the chemical reaction for the production of FAME (Padhi & Mishra, 2021).



Figure 2.2 The trans-esterification reaction involved from triglyceride to FAME

2.3.1 Transesterification process

Palm oil transesterification yielded up to 98 per cent methyl ester, which having a kinematic viscosity of 3.149 cSt and a density of 0.8585 gr/ml. It has been proven to be in compliance with the SNI 7182:2015 biodiesel standard, having a kinematic viscosity of 2.3- 6 cSt and a density of 0.85-0.89 gr/ml. Because the glycerol chain is disrupted in the intermolecular interactions in oil, palm oil and methyl ester have different densities and viscosity. The composition of the palm oil methyl ester produced is shown in Table 2.4.

Fatty Acid	Palm Oil (%)	Methyl Ester (%)
Caprylate	0	0.0409
Caprate MALAYSIA	0	0.1433
Laurate	0.262	0.7982
Myristate	5 1.012	4.5129
Palmitoleate	0	1.9136
Palmitate	38.201	41.9158
Stearate	3.637	0
Oleate	45.962	50.2865
Linoleate	10.926	0.3889

Table 2.4 Fatty Acids Composition (Qadariyah et al., 2021)

Figure 2.3 shows the methyl ester GCMS data. Figure 1 indicates that the 9- Octadecenoic acid (methyl oleate) with a composition of 50.2865 percent is created at retention time 23.035 and hexadecenoic acid (methyl palmitate) with a composition of 41.9157 percent is formed at retention time 20.909 (Qadariyah et al., 2021).



Figure 2.3 GCMS of Methyl Ester (Qadariyah et al., 2021)

2.4 Fuel properties of biodiesel

Many of today's diesel engines use direct injection systems, which are more sensitive to fuel spray quality than indirect injection engines and demand a fuel with diesel-like characteristics. Table 2.5 lists the biodiesel's qualities as a fuel generated from FOME, JOME, and diesel fuel. The fatty acid composition of JOME and FOME is listed in Table 2.6. Fatty acids in FOME are made up of long-chain hydrocarbons ranging from C:20 to C:22 according to table 2.6. It is unusual for biodiesel manufactured from edible and non-edible oils to have long-chain hydrocarbons in it (or only in negligible amounts).

Table 2.5 Biodiesel fuel properties from FOME, JOME, and diesel fuels are summarised here (Kathirvelu et al., 2017)

Fuel Property	Unit	Source	Diesel	Limits as per IS 15607-2005 ASTM D6751	JOME	FOME
Density at 15 °C	kg m ⁻³	Measured	830	860-900	882	890
Kinematic viscosity at 40 °C	cSt	Measured	3.52	1.9-6.0	4.5	5.2
Flash point	°C	Measured	54	120 (minimum)	160	157
Calculated cetane index	-	Measured	50	-	54	53
Calorific value	MJ kg ⁻¹	Measured	43.5	-	39.6	38.7
Element O	wt%	Given by Supplier	-	-	10.8	8.1

Table 2.6 Fatty acid content of fish oil methyl esters (FOME) and jatropha oil methyl esters (JOME) in terms of weight percent (JOME) (Kathirvelu et al., 2017)

Types of fatty acids	Chemical Structure	Type ^a	JOME ^b	FOME ^b
Myristic acid	C14:0	S	0.7	4.9
Palmitic acid	C16:0	S	15.3	19.4
Palmitoleic acid	C16:1	US	_	6.4
Heptadecanoic acid	C17:0	S	_	1.7
Stearic acid	C18:0	S	9.6	3.8
Oleic acid	C18:1	US	40.6	20.2
Linoleic acid	C18:2	US	33.4	3.2
Linolenic acid	C18:3	US	0.3	1.2
Arachidic acid	C20:0	S	_	3.5
Eicosadienoic acid	C20:2	US	_	0.4
Eicosatetraenoic acid	C20:4	US	_	2.2
Eicospentaenoic acid	C20:5	US	_	7.8
Behenic acid	C22:0	S	_	1.2
Docosapentaenoic acid	C22:5	US	_	3.2
Docosahexaenoic- acid	C22:6	US	_	18.2
Saturated fatty acids (S)	C14-C18		25.6	33.3
Unsaturated fatty acids (US)	C18:1,2,3		74.3	24.6
Long carbon-chain fatty acid	C20-C22		_	36.7

^a S - Saturated fatty acid, US - Unsaturated fatty acid.

^b Data provided by the supplier.

JOME contains Long-chain hydrocarbons aren't present (C:20 to C:22). Saturated fatty acid methyl esters make up 25.6 percent of JOME and 33.4 percent of FOME, respectively (Kathirvelu et al., 2017). The physiochemical characteristics of vegetable oil are definite by the fatty acid composition. Fatty acids are defined by the length of the carbon chain and the number of double bonds. In vegetable oils, palmitic, stearic, oleic, linoleic, and linolenic acids are prevalent fatty acids. Table 2.7 lists the most prevalent fatty acids present in vegetable oil (Che Mat et al., 2018).

Table 2.7 Fatty acid that can be found in both edible and non-edible vegetable oils (Che Mat et al., 2018)

Fatty Acid	Carbon Number	Mol. formula	Edible	Edible			Non-edible		
			Palm	Rapeseed	Soybean	Sunflower	Jatropha	Karanja	Castor
Lauric (dodecanoic)	C12:0	C12H24O2	0.1-0.2	-	< 0.1	-	-	-	-
Myristic (tetradecanoic)	C14:0	C14H28O2	0.8-0.9	< 0.1	< 0.1	< 0.1	0.15	-	-
Palmitic (hexadecanoic)	C16:0	C16H32O2	39.5-47	3.3-6	8-13.3	5.6-7.6	14.4-15.6	10.9	1.4-2.0
Palmitoleic (hexadecenoic)	C16:1	C16H30O2	< 0.6	0-3.0	0.2-13.3	< 0.3	0.69	-	-
Stearic (octadecanoic)	C18:0	C18H36O2	3-6	1.3-6	3-5	3-6	5.8-10.5	7.9	1.1 - 2.0
Oleic (octadecenoic)	C18:1	C18H34O2	36-44	52-65	18-26	14-40	42-43	53.6	3.4-6.0
Linoleic (octadecadienoic)	C18:2	C18H32O2	6-12	18-25	49-57	48-74	30.9-35.4	21.3	4.0-4.8
Linolenic (octadecatrinoic)	C18:3	C18H30O2	< 0.5	8-11	5-9	< 0.2	0.2	2.1	< 0.6
Ricinoleic	C18:1 (OH)	$C_{18}H_{34}O_3$	-	-	-	-	-	-	86-88

Another important feature of FOME polyunsaturated fatty acids is present acids have more than three double bonds, but JOME lacks them. FOME has low oxidation stability due to the high amount of unsaturated fatty acids. As a result, FOME should be used as soon as feasible after preparation to prevent precipitation in the fuel injector and pump. Because biodiesel has different physical and chemical properties than petroleum-based diesel fuel, it will alter engine performance and emissions if used in engines without modification. All biodiesel qualities comply with ASTM D 6751-12 (Kathirvelu et al., 2017).

Table 2.8 highlights numerous essential physio-chemical parameters of pure biodiesel generated from mixed PO, according to a literature review. The table above shows that the characteristics of biodiesel and its blends are quite comparable to those of diesel and that they fall within the ASTM D6751-12 restrictions. (v S R Krishna & K, 2018).

	180					
Properties	KIII	Diesel	B5	B20	B30	B100
Density (kg/m ³)	GITI TE	830	838	854	860	868
Specific gravity	"BAINI	0.833	0.839	0.854	0.860	0.869
Kinematic vis-	del (2.2	2.4	3.5	3.65	3.95
cosity (cSt)	ا ملاك	ىل مليسىي	ڪيند	يتي بيھ	ويبؤمرهم	
Acid value		0.35	0.37	0.40 AVELA	0.42	0.48
(mgKOH/gm)	UNIVER	KOITI IEK		IALAT SIA	MELAKA	
Flash point (℃)		60	64	72	80	160
Fire point (°C)		68	70	82	92	170
Calorific value (l	kJ/kg)	44800	43926	42639	41091	38987

Table 2.8 Pure biodiesel and its mixtures have different properties (v S R Krishna & K, 2018).

2.5 Diesel engine operation using Palm oil-based biodiesel and blends

This section delves into the exhaust gas emissions and the performance of compression ignition engines that use palm oil as a biodiesel feedstock. In this section the exhaust gas emissions investigated are exhaust gas temperatures, CO₂, CO, HC, NOx and smoke opacity, while for the engine performance studied is, brake power, torque, specific fuel consumptions. In this section also we can see the difference in exhaust gas emissions and the performance of

compression ignition engines for biodiesel and diesel where there are advantages and disadvantages for these two types of oil.

2.5.1 Engine performance characteristics

2.5.1.1 Brake power

The amount of power generated at the output shaft by the engine is referred to as brake power. According to the findings, biodiesel features, viscosity, lower and higher heating temperature values have an impact on CI engine brake power. Biodiesel and its mixes have a lower heating value than diesel, resulting in a reduction in power (Verma et al., 2021). (Yaqoob et al., 2021) says the same thing. This is due to PO biodiesel's low heating value. Table 2.9 displays the biodiesel important findings for brake power performance characteristics.

 Table 2.9 biodiesel important findings for brake power performance characteristics (Yaqoob et al., 2021).

At higher compression ratios (CP) the PP value decreases for higher bland	
 Artigher compression ratios (CR), the BF value decreases for higher blend proportions as the energy is converted from chemical to mechanical. At CR 21, BP for diesel and B40 is 2.12 kW and 2.07 kW, respectively. Maximum BP is observed for the minor biodiesel proportion of B5 to be 7.9 kW and 5.5 kW for B100 fuel. Engine power is reduced by 6, 8, and 10 kW for B20, B70, and B100 blends. 	[18,32,44]
	 proportions as the energy is converted from chemical to mechanical. At CR 21, BP for diesel and B40 is 2.12 kW and 2.07 kW, respectively. Maximum BP is observed for the minor biodiesel proportion of B5 to be 7.9 kW and 5.5 kW for B100 fuel. Engine power is reduced by 6, 8, and 10 kW for B20, B70, and B100 blends.

2.5.1.2 Torque UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Because of the high viscosity of PO biodiesel, blends become more viscous than pure diesel, impairing atomization and causing spray characteristics to be disrupted during the injection. (Yaqoob et al., 2021). Similarly, for all fuels, greater biodiesel mixes resulted in decreased engine torque across the entire testing speed range. Biodiesel fuel has a higher viscosity than diesel but a lower calorific value which explains the reduction. Furthermore, a higher amount of biodiesel fuel in this blend reduces engine torque (Verma et al., 2021). Fuel spray characteristics may be improved by raising torque, which raises the fuel injection pressure and improves flow. Engine performance and emissions are closely related and influenced by spray characteristics. Because of the variations between spray and injection techniques, and properties, some fuels may require slight engine design changes, such as piston bowl design. Improvements in injection or the surrounding environment can occasionally remedy the issue, such as density and temperature. The nozzle shape can also increase spray characteristics since a non-circular aperture improves air intake. For PO biodiesel blended fuels, all of these modifications can increase engine torque output. Table 2.10 shows the main findings on the torque performance characteristics of diesel engines (Yaqoob et al., 2021).

Table 2.10 main findings on the torque performance characteristics of diesel engines (Yaqoob et al., 2021)

Engine torque	 At 1600 rpm and maximum power, B5 fuel gives about 2 Nm higher torque than petroleum diesel. For B100, B70, and B20, the torque drops about 38.7, 32, and 19.7 Nm compared to petroleum diesel, respectively. 	[44]
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2.5.1.3 Brake thermal efficiency (BTE)

The ratio of the injected fuel's power output to its energy output is referred to as thermal efficiency. This energy is obtained by multiplying the decreased heating value by the injected fuel's mass flow rate, a process known as fuel conversion efficiency (Yaqoob et al., 2021). In comparison to the neat diesel, the thermal efficiency of biodiesel blends (B20, B100) and oil blends (PO20) was shown in figure 2.4 (Gad et al., 2018). Blends of biodiesel have a little lower thermal efficiency than diesel fuel when the engine is running at full power. When compared to diesel fuel, palm oil biodiesel has poor combustion properties and instability, resulting in lower thermal efficiency for biodiesel mixtures (Gad et al., 2018).



Figure 2.4 Thermal efficiency of palm oil and biodiesel mixes varies with engine load

(Gad et al., 2018)

Adding more biodiesel to diesel reduces the thermal efficiency of the brakes because of the fuel's poor spray qualities, high viscosity, high volatility, and low caloric value (Verma et al., 2021). Palm-oil biodiesel blends B20, B100, and P020 have worse thermal efficiency than diesel fuel (Gad et al., 2018).

Figure 2.5 showed the increase in brake thermal efficiency (BTE) as brake power increased. BTE rises with increasing brake power in every situation. BTE of B5 and B20 is comparable to diesel fuel BTE. In comparison to other blends, B30 and B100 have lower BTE. Biodiesel with lower calorific values and viscosity may impact the combination forming procedure, resulting in slow combustion and a loss in BTE. Biodiesel molecules include a small amount of oxygen, which helps in the combustion process (v S R Krishna & K, 2018).



Break thermal efficiency	 Brake thermal efficiency (BTE) is directly proportional to the compression ratio, and for diesel blends, its value can be higher than petroleum diesel. BTE value for diesel, B10, and B20 at full load is 31.2%, 31.8%, and 31.6%, respectively. For the compression ratio of 21, the BTE of the B40 blend comes to a maximum of 31.48%, whereas it is 26.08% for the same conditions using pure diesel. 	[31,45,68]
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2.5.1.4 Brake specific fuel consumption (BSFC)

The quantity of fuel spent per unit of energy at the output shaft is known as specific fuel consumption. (v S R Krishna & K, 2018). For diesel, biodiesel (B100), diesel-palm biodiesel mix (B20), and diesel palm oil blends, Figure 2.6 depicted the change in specific fuel consumption with engine load (PO20). Compared to diesel, palm oil-based biodiesel blends

have a higher specific fuel consumption rate. Fuel usage rose according to the amount of biodiesel added into diesel fuel in biodiesel blends. To run at the same power, a diesel engine utilising a biodiesel blend consumes more fuel than one using pure diesel (Gad et al., 2018).





function of engine load (Gad et al., 2018)

Table 2.12 illustrates the most significant results of the brake specific fuel consumption performance parameters of a diesel engine (Yaqoob et al., 2021).



The specific fuel consumption is related to the braking thermal efficiency (BSFC). The variation in specific fuel consumption (SFC) as a function of brake power is shown in Figure 2.7. For all blends and diesels studied, SFC declined as brake power (BP) increased. B5 outperformed other biodiesel blends in terms of overall performance and was quite close to diesel performance. B20 and B30 have very same SFC. B100 has a lower SFC than diesel, B5,

B20, and B30. Because the calorific value of biodiesel in a blend falls as the amount of biodiesel in the blend grows, the SFC value rises. (v S R Krishna & K, 2018).



Figure 2.7 Variation in specific fuel consumption as a

function of brake force (v S R Krishna & K, 2018)

According to another study, Fig.2.8 shows the graph of specific fuel usage as load increases. According to the findings of the experiments, the usage of certain fuel decreases at low loads (load 10.0 percent 37.5 percent), remains constant at moderate loads (37.5 percent 87.5 percent), and increases at high loads (87, 5 percent 100 percent). This downward trend is due to an insufficient mixing of fuel and air. It produces 1 horsepower in 60 minutes as a result. This just means that it uses less fuel. The chart trend will increase at times due to the quantity of power consumed by the machine to produce 1 horsepower in 60 minutes. The mixture will get rich as a result of large-scale fuel consumption. This is due to the fact that the amount of mass flow air in a diesel motor is largely consistent under all operating conditions. The rich mixture also causes the after-burning stage to not burn all of the fuel, resulting in some wasted fuel (Maksum et al., 2019).



Figure 2.8 BSFC chart vs engine load (Maksum et al., 2019)
Biodiesel generated from palm oil has an effect on engine performance measures such brake thermal efficiency (BTE), brake power (BP), and brake specific fuel consumption (BSFC). Finally, Table 2.13 show how PO biodiesel and its mixes affect BTE, BP, and BSFC (Singh et al., 2021b).



Table 2.13 show how PO biodiesel and its mixes affect BTE, BP, and BSFC (Singh et al., 2021b)

Table 7

Performance and emissions parameters of CI engine operated on WCO biodiesel and its blends.

Instruction TTX (%) BP (W) BS7 (GrAWh) OD HC OD ₂ NOK PM Smoke emission Joba-Dore power 127 W, const. 1500 rpm Fuel: BS0 and B100, (S & W innewsi) (0.02 ± 0.029) for B10 to 0.029) for B10 to 0.029 for 0.020 for B10 to 0.029 for 0.020 for B10 to 0.029 f	Specifications of the	Input variables	Performance parameters			Emission parameters					References	
John Dever SOFGTFTOD, K., Disk for and BLO2, SOFGTFTOD, K., SofGTFTOD, K., SofGTFT, K., SofGTFT, K., SofGTFT, SOFGT, K., So	test engine		BTE (%)	BP (kW)	BSFC (g/kWh)	00	HC	CO2	NOx	PM	Smoke emissions	
Untor/GL/D400 single QL, max power 5.4 (Ref area processor) Fuel: B1 op: 10.5% (B5) and 1 (D2) - 1.5% (Abb) (D2) - 1.5% (Abb) (D2) - 1.7% (Max load) (Can, 2014) QL, max power 5.4 (M at 3000 rpm Fuel: B100; 0.5-4 kW (Basing, fixed 1500 (Data); fixed 1	ohn-Deere 6076TF030, 6 cyl., 15.5:1 CR, max power 127 kW, const. 1500 rpm	Fuel: B50 and B100; Load range: 0-75 kW (25 kW interval)	\downarrow (0.25 ± 0.03%) for B100 and \downarrow (0.24 ± 0.02%) for B50 (at 50 kW load); Higher than diesel fael at 75 kW load	AYSIA	\uparrow (12.73 ± 0.03%) for B100 and \uparrow (5.60 ± 0.02%) for B50	18% and 14% for B100 and B50, resp.	↓ (25.11 ± 0.03%) for B100 and lower for B50 than diesel fuel	-	†12.62% and 1.84% for B100 and B50, resp.	-	-	Lertsathapornsuk et al. (2008)
Kirlokar Fuel: B100, 0.5 - 4.W I (4%) than diesel - Min B80 (b) than diesel - I (10%) than diesel fuel - Hikude & Ps Di, 45, 16, 51 CR, pm pm 0.07 kg/Wh diesel - 1 (10%) than diesel fuel - 1 (10%) than diesel fuel - (2012) J1, 45, 16, 51 CR, max load and fixed goed i (4%) maximum - 1 (00%) than diesel - 1 (11%) the maximum - 1 (11%) the maximum - (2012) J2,51 CR, max load and fixed goed i (4%) maximum - 1 (00%) than diesel - 1 (11,39%) for max Gopal et al. (11%) for low & mortage - 1 (11,39%) for max Gopal et al. (11%) for low & mortage -	Antor/6LD400 single cyl., 4S, DI, 18:1 CR, max power 5.4 kW at 3000 rpm	Fuel: B5 and B10; Varying load and fixed rpm (2200)	1.2% (B5) and 1 1.2% (B10)	-	(5 g/kWh (approx.)	1 51% for max loads; 1 11.8% (low and medium loads)	1 29% for max load; 1 (low & medium loads)	† in smaller amount	1 (8.7%)	-	↓ 7% (Max load)	(Can, 2014)
Single cyt., 45, Dt, AC, Fuel: B100; varying load and fixed speed power 4.4 kW load and fixed speed power 4.4 kW load and fixed speed load and fixed speed (10%) for low 4. medium loads and fixed speed (10%) for low 4. medium loads fixed speed and fixed speed and fixed load and fixed speed and fixed load and fixed load and fixed load f	Kirloskar Engine, single cyl., Dl, 4S, 16.5:1 CR, max power 3.78 kW at 1500 rpm	Fuel: B100; 0.5–4 kW loading, fixed 1500 rpm	4 (4%) than diesel	-	Min BSFG t by 0.07 kg/RWh	4 (45%) than diesel	-		† (10%) than diesel fuel	1(47%) than diesel fuel	-	Hirkude & Padalkar (2012)
Single cyl., 45, WC, Turbocharged, 4 cyl., 45, Dl, WC engine, 51-22:1, max power 3.7 kW at 3600 rpm WC engine, 51-32:1, max power 3.7 kW at 3600 rpm WC engine, 51-32:1, TO 110, Fuel: B100; Varying 3600 rpm 10.55% 114.34% than 40.55% 1	Single cyl., 4S, DI, AC, 17.5:1 CR, max power 4.4 kW	Fuel: B100; varying load and fixed speed	1 (4%) maximum	-	† (0.076 kg/ kWh)	↓ (31%) average	1 (57%) average		† (18.33%) average		↓ (15%) for max load and † (10%) for low & medium loads	Gopal et al. (2014)
Turbocharged, 4 cyl., 4S, DI, speed and fixed load Fuel: B100; varying speed and fixed load † (1.8%) af 2400 rpm † (8.kW) 1 100 g/kWh at 3600 rpm † (40%) at 1 00% loading) Small † Small † An et al. (20) 4S, DI, power 75 kW at 3600 rpm rpm 1 00.5 kW if (40%) at rpm 1 (40%) at 1 (0.05 kW 1 (40%) at 1 (1.1 (40%) at 1 (40%) at 1 (1.1 (40%) at 1 (1.1 (40%) at 1 (1.1	Single cyl., 4S, WC, max power 7bhp, 17.5:1 CR Const 1500 rpm	Fuel: B100; varying load and fixed speed	f (1-1.85%)	-	† than diesel fuel	Approx. same	‡ than diesel duel	Approx. same	† than diesel fuel		-	Sudhir et al. (2007)
VCR engine, 4 cyL, 4S, DI, WC, CR max power 3.7 kW TDI 110, turbocharged, 4 cyL, DI, WC, max power 82 kW at 3980 r 85.9-160, Fuel: B5, B10, B20, Fuel: B10, B2	Turbocharged, 4 cyl., 4S, DI, 18.5:1 CR, max power 75 kW at 3600 rom	Fuel: B100; varying speed and fixed load	† (1.8%) af 2400 rpm	4 (8 kW) at 3600 rpm	1 100 g/kWh for 25% loading at 2400 rpm	† (40%) at 3600 rpm	4 (50% and 100% loading)	4 (2%) at 3600 rpm	Small † (1200 rpm) and 100 ppm ↓ (3600 rpm)			An et al. (2013)
TDI 110, Fuel: B100; Varying - 10.55% 114.34% than 117.14% than - 18.05% 114.5% than - 122.46% than (Utlu and Ko turbocharged, 4 speed (1500-4500 than diesel fuel diesel fuel than diesel fuel diesel fuel 2008) cy4., DI, WC, max rpm) diesel fael fael fael 2008) power 82 kW at 3850 rpm S850 rpm Fuel: B5, B10, B20, UNIVERSITI TEKK NIKAAL (0.038, 0.14, L) (0.039, L) (10, 3, 7) f.00.05, 0.09, E) (0.012, L) Lin et al. (201	VCR engine, 4 cyL, 4S, DI, WC, CR range 5:1-22:1, max power 3.7 kW	Fuel: B40; CR range (18-22), fixed load	51 (549) at CR 21	↓ (0.05 kW) at CR 21	1 (0.055 kg/ kWb) at CR 21	Small † at CR 21 and ↓ (0.1%) at CR 20	† (10 g/kWh) at CR 21	Small † at CR 22	† 100 ppm at CR 22 and smäll † at CR 21	يبونه	91	Muralidharan & Vasudevan (2011)
Cummins B5.9-160, Fuel: B5, B10, B20, - + + + + + + + + + + + + + + + + + +	TDI 110, turbocharged, 4 cyl., DI, WC, max power 82 kW at 3850 rom	Fuel: B100; Varying speed (1500–4500 rpm)	INIVED	10.55% than diesel fuel	14.34% than diesel fuel	17.14% than diesel fuel	MAI	1 8.05% than diesel** fuel	1.45% than diesel fuel		122.46% than diesel fuel	(Utlu and Koçak, 2008)
DI, and B30 1.06%, 1.71% 0.17, and 0.177, and 9 g/ 0.09, and 0.018, 17.9:1 CR, max and 3.42% 0.26 g/kWh 0.248, and kWh resp.) 0.15 g/kWh 0.017, and power 118 kW at resp.) resp.) 0.321 g/kWh resp.) 0.017 g/kWh 2500 rpm resp.) resp.) resp.) resp.) resp.)	Cummins B5.9-160, DI, 17.9:1 CR, max power 118 kW at 2500 rpm	Fuel: B5, B10, B20, and B30	JNIVER	0111	1 (0.385%) 1.06%, 1.71% and 3.42% resp.)	4 (0.13, 0.14, 0.17, and 0.26 g/kWh resp.)	4 (0.093, 0.177, 0.248, and 0.321 g/kWh resp.)	† (1, 3, 7) and 9 g/ kWh resp.)	f (0.05, 0.09, 0.09, and 0.15 g/kWh resp.)	1 (0.012) 0.018, 0.017, and 0.017 g/kWh resp.)	./4	Lin et al. (2011)
MWM D229/4, 4 cyl., Fuel: B50, B75; load ↑ (46.1%) ↑ (23.5%) for ↑ (13.3%) ↑ (6.5%) Valente et al. 45, DI variation:0-25 kW and fixed speed (2012)	MWM D229/4, 4 cyl., 45, DI	Fuel: B50, B75; load variation:0-25 kW and fixed speed	-	-	-	† (46.1%)	† (23.5%) for B50 blend	† (13.3%)	† (6.5%)	-	-	Valente et al. (2012)
4 cyl., 45, Dl, WC, Fuel: B100; fixed - + (60 g/kWh) ↓ (0.3%) for Small ↓ at Small ↑ at ↓ at medium - + (35%) at Ozsezen & Ca 21.47.1 CR, max load and varying at medium all range of 3000 rpm speeds and † 2000-3000 rpm (2010) power 38.8 kW at speed (1000-3000 speed speeds ↓ (6 ppm) at and ↓ (1%) (10 ppm) at and ↑ (10%) at 4250 rpm rpm) 1000 rpm 1000 rpm 1000 rpm 1000-1500 rpm	4 cyl., 48, DI, WC, 21.47:1 CR, max power 38.8 kW at 4250 rpm	Fuel: B100; fixed load and varying speed (1000-3000 rpm)	-	-	† (60 g/kWh) at medium speed	↓ (0.3%) for all range of speeds	Small ↓ at 3000 rpm and ↓ (6 ppm) at 1000 rpm	Small † at 3000 rpm and ↓ (1%) at 1000 rpm	↓ at medium speeds and † (10 ppm) at 1000 rpm	-	† (35%) at 2000–3000 rpm and † (10%) at 1000–1500 rpm	Ozsezen & Canakci (2010)
YC6M220G, 6 cyl., Fuel: B0, B20, B50, - - - 4 (20.58%) - Meng et al. (20.58%) 4S, DI, WC, Max B100 and refined for all blends for refined for refined	YC6M220G, 6 cyl., 4S, DI, WC, Max	Fuel: B0, B20, B50, B100 and refined	-	-	Approx. same for all blends			-	_	↓ (20.58%) for refined	-	Meng et al. (2008)

Table 7 (continued)				MAI	AYSIA							
Specifications of the	Input variables	Performance	e paramete	rs		Emission parame	eters					References
test engine		BTE (%)		BP (kW)	BSFC (g/kWh)	со	НС	CO ₂	NOx	PM	Smoke emissions	
power 162 kW, Max speed 2200 rpm	B20); Speeds: 1300 and 2200 rpm		KW			↓ (18.60%) for refined B20 than B0 blend	↓ (26.70%) for refined B20 than B0 blend			B20 than other blends		
4 cyl., DI, WC, 19:1 CR, max power 88 kW at 3200 rpm	Fuel: B100; Varying load: (28, 84, 140, 196 and 224 Nm) and Fixed speed of 1800 rpm	↓ (2%)	ET E	-	↑ (50 g/kWh)	Same for max load, ↑ (3 g/ kWh) at low load	Small↓for all range of loads	-	↑ (1 g/kWh)			Zhu et al. (2016)
Single cyl., 48 WC, 16.5:1 CR, max 3.7 kW at 1500 rpm	Fuel: B20; Varying loads: (2, 4, 6 and 8 N) and fixed speed	↓ (6%) at 8 and ↓ (2%) a load	N load at 2 N	Small ↑ at 8 N load	↑ (0.001 kg/ kWh) at 8 N load and ↑ (0.0015 kg/ kWh) at 2 N	↓ (70.58%) at 8 N load and ↓ (75%) at 2 N load	Small↓ at 8 N load and ↑ (33%) at 2 N load	↓ (43%) at 8 N load and ↓ (30%) at 2 N load	↑ (8%) at 8 N load and ↑ (20%) at 2 N load			Pradhan et al. (2016)
6 cyl., 4S, DI, WC, 17:1 CR, max 18 kW at 1500 rpm	Fuel: B20; Varying loads: (2, 3.3 and 4.6 kW) and fixed speed (1500 rpm)	↓ (2 %) at 4. load	6 kW	tol	load ↑ (75 g/kWh) at 4.6 kW load	↓ in small amount	↑ (10 ppm) at 4.6 kW load	↓ in small amount	↑ in small amount	ر س	اونو	Isik et al. (2017)
Ford Cargo turbocharged, 6 cyl., 4S, DI, WC, 16.4:1 CR, max 136 kW at 2400 rpm	Fuel: B100 (EE and ME); Variable speed (1100, 1400 & 1700 rpm) and Constant load (600 Nm)	-	UNI	VE	11.44% for EE and 14.17% for ME	↓ 28.84% for EE and ↓ 22.30% for ME	↓ 38.29% for EE and ↓ 29.36% for ME	↑ 0.92% for EE and ↑ 2.08% for ME	↑ 11.32% for EE and ↑ 10.80% for ME	A ME	LAKA	Sanli et al. (2015)
6 cyl., 4S, IDI, AC, 19:1 CR, max power 12 kW	Fuel: B100; Varying load (1, 3.6, and 9 kW) and fixed speed of 1800 rpm	† (1.89%)		-	↑ (8.64%)	↑ (33.28%)	↑ (78.84%)	-	↓ (1.68%)	-	_	Atmanli (2016)

D. Singh et al.

2.5.2 Exhaust gas emissions characteristics.

2.5.2.1 Exhaust gas temperatures,

For all fuels, the temperature of the exhaust gas increases as the engine load increases. Biodiesel B100, biodiesel blend B20, and oil mix PO20 exhaust gas temperatures are shown in Fig. 2.9.. For the full engine load, biodiesel blends provide higher exhaust gas temperatures than fossil diesel (Gad et al., 2018). Because a higher oxygen percentage helps the combustion process, EGT for biodiesel fuel has increased. Biodiesel fuel's low volatility and increased viscosity cause it to burn slowly, resulting in an increase in temperature (Verma et al., 2021).



Figure 2.9 Variation in exhaust gas temperature for palm oil and biodiesel mixes as a function of engine load (Gad et al., 2018)

A lower cetane number fuel has a longer ignition delay and accumulates more fuel-air mixing, resulting in a faster heat release rate and greater temperature at the start of the combustion process (Verma et al., 2021). Table 2.14 summarises the key findings of the performance parameters and exhaust gas temperature in a diesel engine (Yaqoob et al., 2021).

Table 2.14 key findings of the performance parameters and exhaust gas temperature in a diesel engine

Exhaust gas temperature	 When CR is low, e.g., 18, the blends' EGT is high compared with the standard diesel. When CR is high, e.g., 21, the EGT for the WCO biodiesel blends is lower than petroleum diesel. For B40, the maximum temperature is 200.61 °C and 233.48 °C for petroleum diesel. Maximum power obtained at 50–55 rpm and EGT for WCO biodiesel came out to be 552 °C, and for petroleum diesel, 585 °C, which is 5.6% lower for biodiesel than petroleum diesel.
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2.5.2.2 Smoke opacity

Smoke in exhaust emissions is created by incomplete fuel combustion, and engines with fewer smoke emissions are a sign of better fuel combustion. This is caused by the fuel's poor atomisation (Yaqoob et al., 2021). Figure 2.10 shows the smoke opacity emissions of all biodiesel blends as a function of engine load (Abed et al., 2019).



Figure 2.10 Variation in smoke emissions for biodiesel mixes as a function of engine

load (Abed et al., 2019).

Under identical operating conditions, smoke emissions of biodiesel blends were lower than diesel fuel due to oxygen in the molecular structure, resulting in improved combustion and lower smoke emissions.. Table 2.15 summarises the important findings of the smoke emission characteristics in a diesel engine (Yaqoob et al., 2021).

Table 2.15 important findings of the smoke emission characteristics in a diesel engine (Yaqoob et al., 2021).

- For the unmodified engine, smoke emission for B0, B10, and B20 is 83.3 HSU, 78 HSU, and 70 HSU, respectively, at full load condition.
 Smoke emission decreases as the percentage of biodiesel increases in the blended fuel.
 Under all BMEP's, B100 fuel shows less smoke emission than B0 fuel.
 - Biodiesel smoke opacity is about 60% less than petroleum diesel.

2.5.2.3 CO₂

CO₂ is the least harmful greenhouse gas since its life cycle can be easily regulated by planting energy crops across the world.. Exhaust gas temperature and compression ratio (CR) are two important elements that determine CO₂ emissions. Because of proper combustion, the emission concentration is high at lower CR (Yaqoob et al., 2021). CO₂ emissions from biodiesel blends derived from diesel oil, Jatropha plants, palm oil algae and waste cooking oil are shown in Figure 2.11 for different engine loads and engine types (Abed et al., 2019).



Figure 2.11 Effect of engine load on CO_2 emissions from biodiesel blends (Abed et

al., 2019)

As the percentage of biodiesel in diesel grows, the quantity of CO_2 generated increases. The trend toward higher-load engines is rising because biodiesel burns more gasoline at higher loads and has more oxygen available in its molecule. Table 2.16 summarises the most relevant discoveries on the CO_2 emission characteristics of a diesel engine (Yaqoob et al., 2021).

Table 2.16 the most relevant discoveries on the CO_2 emission characteristics of a diesel engine (Yaqoob et al., 2021)

CO₂ emissions
 At CR 21, the blend B40 shows less CO₂ emission.

2.5.2.4 CO

CO emissions are proportional to the fuel's physical and chemical qualities, such as peak engine temperature, air-to-fuel ratio, time available for complete combustion and oxygen availability at high engine speeds. Due to reduced atomization, the higher viscosity of the PO mixes typically increases CO emission in unmodified engines. (Yaqoob et al., 2021). Figure 2.12 shows carbon monoxide emissions for biodiesel blends B10 and B20 made from diesel, palm, Jatropha, algae, and waste cooking oil.(Abed et al., 2019).



Figure 2.12 CO emission changes with engine load for biodiesel mixes (Abed et al.,

2019)

CO emissions dropped with increasing engine load at part load, then increased at full load for all tested fuels. Because biodiesel blends had more oxygen molecules and had a lower carbon content than diesel fuel, they created less carbon monoxide, resulting in improved combustion. The main findings of the emission characteristics, CO in a diesel engine are summarised in Table 2.17 (Yaqoob et al., 2021).

Table 2.17 main findings of the emission characteristics, CO in a diesel engine (Yaqoob et al., 2021)

 CO emission increases for higher compression ratios and B40 blend show about an equal percentage of emissions similar to diesel, while B20, B60, and B80 give less emissions than diesel.

CO emissions

- At full load with no modification to the engine, the CO emission is 0.41 vol%, 0.37 vol%, and 0.32 vol% for B20, B10, and B0, respectively.
- The CO emissions for B5 and B100 blends are 9% less and 32% less than petroleum diesel.

2.5.2.5 HC

The amount of unburned HC in the exhaust is determined by the cylinder's maximum air and fuel mixture. Increased HC emissions may be a consequence of prolonged ignition delays when fuel builds in the combustion chamber (Yaqoob et al., 2021). Diesel oil, Jatropha, palm, algae, and waste cooking oil biodiesel mixtures showed "variation in HC emissions with engine load," as shown in Figure 2.13 (Abed et al., 2019).



Figure 2.13 HC emission changes with engine load for biodiesel mixes (Abed et al.,

2019).

All tested fuels had lower HC emissions at half engine load but higher emissions at full engine load. Large fuel particle size, injection time, and nozzle choking all increased combustion timing. The absence of oxygen generated by engine activity results in the formation of a fuel-rich mixture. The oxygen content in diesel fuel rises when biodiesel is introduced, resulting in improved combustion and fewer HC emissions. The important findings of the emission characteristics, HC, in a diesel engine are summarised in Table 2.18. (Yaqoob et al., 2021).

Table 2.18 important findings of the emission characteristics, HC, in a diesel engine (Yaqoob et al., 2021)

HC emissions	 For B40, the HC emission increases with the increase in CR. For blends B20, B60, and B80, the HC emission is less than the standard diesel at high CR. The unburnt HC amount for B100 is found to be 0.062 g/kWh, while for B0, it is 0.081 g/kWh at minimum BP. The unburnt HC amount is 66, 64, and 60 ppm for B20, B10, and B0 fuels, respectively, without modifying the engine.
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2.5.2.6 NOx

Diesel exhaust contains harmful gases such as NOx, which, when collected in the environment, causes acid rain. NOx was produced in the exhaust of CI engines due to the thermal NOx procedure, which is impacted by the burned mixture temperature, the constrained air/fuel ratio, and the dwell duration at higher temperatures in the engine cylinder (Yaqoob et al., 2021). The influence of engine load on NOx emissions was demonstrated in Fig. 2.14 for diesel fuel, Jatropha, algae, palm oil, and waste cooking oil biodiesel (Abed et al., 2019).



Figure 2.14 NOx emission changes with engine load for biodiesel mixes (Abed et al.,

2019)

in comparison to diesel fuel, All biodiesel mixes had higher NOx emissions than diesel oil. Regardless of whether fuel is used, the amount of NOx produced increases as engine load increases. This is because more fuel is burned, and thermal/Zeldovich NOx synthesis is caused by a rise in peak cylinder temperature The adiabatic flame temperature, which impacts the emission rate of NOx, is closely linked to the peak cylinder temperature. Higher peak cylinder temperatures and NOx percentages are caused by high adiabatic flame temperatures (Abed et al., 2019).

NOx emissions from biodiesel are a severe problem, and they are impacted by a number of factors such as biodiesel type, engine technology and design, operating conditions, combustion temperature, and injection settings. The effective parameters and route of NOX emission are depicted in Figure 2.15 (Verma et al., 2021).



Figure 2.15 NOX emission route and effective factors during combustion (Verma et



CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter concentrates on the proposed research technique for biodiesel produced from palm oil via the transesterification process. Diesel engine performance and exhaust emissions for burning palm-oil blend with diesel fuel were evaluated. This methodology allows for a thorough understanding of diesel engine performance and emissions, such as horse power, torque, brake specific fuel consumptions, CO₂, CO, HC, and NOx, of biodiesel blends. This chapter discusses the importance of based theory and a constructivist approach to it.

Biodiesel from palm oil by-products and mill effluent can provide numerous benefits to various parties. However, more research is needed, such as developing an efficient conversion method to produce biodiesel with high yield and quality while minimising production costs and environmental impacts; developing a comprehensive strategy to connect and transport wastes from their source to production facilities; and conducting a detailed study and simulation using computational approach to understand the reaction possibilities and optimise its production rate.

Horse power, torque, brake specific fuel consumption, CO_2 , CO, HC, and NOx, of biodiesel blends will be generated using an engine dyno. This result is the primary source of information for this topic.

3.2 Flow Chart

Planning must be done correctly in order to identify all relevant data and requirements, including hardware and software. Two significant components in the planning stage are data collecting and the utilisation of hardware and software requirements. The most important component of the planning process should be created before the procedure is completed to ensure that the project runs smoothly and easily. This planning strategy is important in project management to ensure that the project is completed on schedule. Process planning can also be led to ensure that the process is followed in a systematic manner.

In order to conduct this study, a flowchart was designed for the overall project, as shown in figure 3.1. This flow chart depicts the biodiesel process from literature review through experiment and finally to the analysis and reporting of performance and exhaust emissions of a diesel engine. The following figure show the overall flow chart for this project or research.





No

Figure 3.1 Flow Chart

3.3 Type of feedstock

Palm oil was chosen as the feedstock for making biodiesel in order to study the performance and emissions of a diesel engine. The percentage of palm oil biodiesel blends used is between 20% and 30%. Table 3.1 shows the physical properties of palm oil.

Properties	Value	Method
Density at 40°C (kg/m ³)	898.50	ASTM D-4052-11
Kinematic viscosity at 40°C (<u>SS</u> t)	44.97	ASTM D-445
Water content (191%)	0.1940	ASTM D-4377
Free fatty acid content (35t%)	0.0550	Titrimetric
Acid value (mg KOH/g oil)	0.1095	ASTM D-664
Iodine value ())(%)	59.39	AOCS Cd 1-25

Table 3.1 the physical properties of palm oil. (Zahan & Kano, 2018)

There are numerous advantages to using palm oil as a feedstock for biodiesel production, including the fact that the engines tested started smoothly with minimal knocking noise. Furthermore, with normal carbon build-up in the engine nozzles and comparable fuel consumption, much cleaner exhaust emissions were measured. Furthermore, due to its greater flash point, palm-biodiesel did not form explosive vapour.

3.4 Type of machine

This project used a 125 HP Blower-Cooled AC Engine Dynamometer from the Technologies Laboratory at Universiti Teknikal Malaysia Melaka's Faculty of Mechanical and Manufacturing Engineering Technologies (UTeM). Figure 3.2 shows a 125 HP Blower-Cooled AC Engine Dynamometer.

To assess the engine output braking power, the machine provided an AC generator with a maximum electric power output of 10.5 kW, a load controller, and other auxiliary items that were directly attached to the test engine. A sharp-edged orifice mounted in the side of an air box, attached to the engine inlet to dampen the pulsing airflow into the engine, was used to monitor intake airflow. The pressure drop across the aperture was measured using a U-tube manometer. Temperature measurements were taken using calibrated thermocouple probes of type (K) at several locations in the experimental setup, including the intake air manifold and exhaust gas. A speed tachometer was used to measure the rotating speed of the crankshaft. On the back side of the panel, at the highest point, two 10 litre fuel tanks were placed for storing the fuels. On the front side of the panel, one burette with a stopcock and two-way valves was attached for fuel flow measurements and switching between diesel and biodiesel fuels. Various exhaust gas emissions such as CO, HC, and NOx were measured using an MRU DELTA 1600-V Gas Analyzer.



Figure 3.2 125 HP Blower-Cooled AC Engine Dynamometer.

3.5 Biodiesel Production

3.5.1 Blending Process

At a low stirring rate, palm oil/palm oil methyl ester was added to diesel. Before analysis, the mixture was stirred for 30 minutes and left to attain equilibrium. 20%, and 30% of palm oil/palm oil methyl ester were added in volume percentages.



3.6 Identification of Engine Parameters

At the Faculty of Mechanical and Manufacturing Engineering Technologies, the project programme was carried out using a single cylinder, four stroke, air cooled, direct injection, naturally aspirated, constant compression ratio diesel engine with a developing power of 5.775 kW. (UTeM). The engine's technical specifications are listed in Table 3.2.

Parameters	Specification
Model	170FA
Туре	Vertical Air-Cooled Diesel Engine
Number of cylinders	1
Number of Cycle	4 stroke
Displacement (CC)	211
Bore X Stroke (MM)	70 X 55
Engine Speed (RPM)	2.5kW (3.4PS)/3000
Rated Output	3.8
Shaft Type	19MM Key & Thread
Fuel Tank Capacity (L)	2.5
Lube Tank Capacity (L)	0.75
Dimension (LxWxH) (MM)	332x384x416

Table 3.2 Engine specification

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3.7

3.7.1 Expected Result

As shown in Table 3.3, pure diesel (D100) is projected to improve the performance of diesel engines. At a certain load, such as no load, half load, or full load, the engine's performance and exhaust emission may be optimised.

Engine	Speed,RPM	Нр	Torque	Brake specific fuel		CO2	HC	NOX
load kW		(Hp)	(N-m)	consumption kg/kW.hr	(%)	(%)	(1/x),ppm	(1/x),ppm
0	0	0.207	0.7	0.28	0.15	1.2	11	45
0.4	1400	0.463	1.7	0.26	0.17	3.2	15	110
1	2800	0.689	1.8	0.24	0.2	5.5	22.5	180

Table 3.3 Engine performance and Exhaust Emission of Pure Diesel D100 on diesel engine



Table 3.4 shows another predicted result from this investigation. Exhaust emission graphs is shown in table 3.4.



Table 3.4 Exhaust Emission graph



This graph from table 3.4 displays the form of the graph for pure diesel according to what is necessary, such as carbon monoxide, which exhibits an increasing pattern when the applied load is increasing. Due to increased gasoline usage, a richer air-fuel combination resulted, which caused this problem. Next for Diesel fuel's carbon dioxide graph rises in direct proportion to the increase in applied load, which is exactly what we want to see. Due to the diesel fuel's presence of oxygen gas, this rise has occurred. Next for hydrocarbon emission, as the load rises, the hydrocarbon on the graph increases as well. This was due to the fact that when more fuel was injected "at greater loads," there was less oxygen available. Last one for emission, Nitrogen oxide graph showed as the load rises, the hydrocarbon on

the graph increases as well. This was due to the fact that when more fuel was injected "at greater loads," there was less oxygen available.

In addition, the results of the graphs of engine performance are intended to be shown in this research. Table 3.6 displays an example of an engine performance graph.



Table 3.5 engine performance graph.



The graph results for this pure diesel engine show the same findings and accomplish what is required in terms of engine performance. for instance According to the horse power graph, the slope steepens from zero to full load because the piston pushes frequently, resulting in more horsepower production and the engine not losing power throughout the combustion process. According to the torque graph, the curve steepens from zero load to middle load and gradually becomes constant from middle load to full load due to rising load. The engine can still accelerate from zero to medium load since the load applied is modest, but when nearing full load, the engine cannot create more torque and it becomes constant throughout the run. According to the particular fuel consumption graph, the slope steepens from zero load to full load as the load increases. Increased engine load causes the engine to burn more gasoline during acceleration. This behaviour will help the engine maintain the load and prevent overloading the engine.

3.8 Summary

This chapter opens with an overview of the biodiesel engine performance and exhaust emission research that was utilised throughout the project. The trial's approach encompassed the optimal feedstock, engine parameter, and machine type used in this biodiesel experiment. B20 and B30 biodiesel samples were used in the testing of diesel engines. Engine performance and exhaust emissions were also be examined such as horse power, torque, and brake specific fuel consumption. CO, CO₂, HC, NO_x, and other exhaust emissions were also recorded.



CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the results and analysis of diesel engine performance and exhaust Emission for burning palm oil blends with diesel fuel that have been applied on a diesel engine at different engine loads from zero to full load. Case studies are performed to demonstrate the engine performance such as Horsepower, Torque, and Brake Specific Fuel Consumption. The case studies performed also demonstate the exhaust emission such as CO₂, CO, HC, and NOx. The case study is based on the ever increase in global energy demand, consumption of depletable fossil fuels, exhaust emissions and global warming that happend it now. It is important to note that, these case study aims about ability Palm oil biodiesel to become alternative fuels. The results of both engine performance and exhaust emission was analysed based on the shape of the resulting graph between three different types of biodiesel blends, D100, B20, and B30 as well as the performance and emission estimation results provided by the research paper. ل مليسيا ملاك

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4.2 Engine peformance analysis

Table 4.1, 4.2, and 4.3 shows the results of diesel engine testing, which varied from D100 to B30, with D100 being pure diesel and B20 and B30 being palm oil biodiesel. It is found that when the mix ratios change, the horsepower and torque production increase as the engine loads increase. However, when the blend ratios changed, the brake-specific fuel consumption reduced differently as the engine load rose. Nonetheless, for ease of comparison, the horsepower, torque, and brake specific fuel consumption for each biodiesel mix are presented on a graph.

Engine	Speed,RPM	Нр	Torque	Brake specific fuel
load kW	Mr.	(Hp)	(N-m)	consumption kg/kW.hr
0	0	0.207	0.7	0
0.4	1400	0.463	1.7	0.50
1	2800	0.689	1.8	0.24
14	linn .			

 Table 4.1 Results of diesel engine testing D100

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 Table 4.2 Results of diesel engine testing B20

Engine	Speed,RPM	Нр	Torque	Brake specific fuel
load kW		(Hp)	(N-m)	consumption kg/kW.hr
0	0	0.179	0.6	0
0.4	1400	0.337	0.8	1.07
1	2800	0.897	2.3	0.19

Engine	Speed,RPM	Нр	Torque	Brake specific fuel
load kW		(Hp)	(N-m)	consumption kg/kW.hr
0	0	0.095	0.3	0
0.4	1400	0.508	1.8	1.43
1	2800	0.705	2.0	0.32

Table 4.3 Results of diesel engine testing B30

4.2.1 Horsepower

Figure 4.1 indicates that engine load is directly proportional to horsepower output. In other words, as engine load increases, so does horsepower output. B20 and B30 have decrease percentages of 0.04% and 0.05% when compared to D100, respectively. According to the computed percentage drop, the loss in engine power of the biodiesel mixture was not considerable when compared to conventional diesel, D100. However, the graph shows that the low energy content of biodiesel per volume, resulting in poor horsepower output, happened in the start. (Verma et al., 2021; Yaqoob et al., 2021) same thing what happened to this article horsepower's graph.



Figure 4.1 Variation of horsepower with engine load for palm oil biodiesel blends.

4.2.2 Torque

The torque is also closely connected to the applied engine load, as seen in Figure 4.2. In other words, when engine load grows, so does torque. This is because turning on the diesel engine demands a lot of force, and as the engine load grows, so does the torque. This rise graph just depicts the overall trend. When comparing torque according to biodiesel blend ratio, it is noticed that B20 and B30 are lower than conventional diesel, D100 at first. This is due to the fact that biodiesel fuel has a higher viscosity than conventional diesel, D100, but a lower calorific value, which explains the initial decline (Yaqoob et al., 2021). This demonstrates that the usage of biodiesel in diesel engines is somewhat weaker than standard diesel since the diesel engine is turned on for an extended period of time.



Figure 4.2 Variation of Torque with engine load for palm oil biodiesel blends

4.2.3 Brake specific fuel consumption

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The brake-specific fuel consumption trend graph is inversely correlated with the applied engine load, as shown in Figure 4.3. According to the positions of the three graphs, the brake specific fuel consumption of biodiesel mixture is higher than that of conventional diesel. This comparison may be observed at 0.4 kW engine load, when the brake specific fuel consumption of each biodiesel blend varies. Whereas a B30 has a brake specific fuel consumption of 1.43kg/kW.hr and the B20 has a brake specific fuel consumption of 0.50kg/kW.hr, the conventional diesel D100 has a brake specific fuel consumption of 0.50kg/kW.hr. According to the percentage increase, B30 has the greatest BSFC value and takes more fuel to create 1 KW of electricity than normal diesel (D100) (Maksum et al., 2019). The lower calorific value of biodiesel compared to conventional diesel results in a greater BSFC from a higher percentage blend ratio (Gad et al., 2018).

Furthermore, increased oxygen content in biodiesel contributes to the reduced calorific value. Despite the fact that biodiesel burns better than conventional diesel, the oxygen in biodiesel takes up space in the mix and raises the fuel consumption rate marginally. As a result of the greater oxygen concentration in biodiesel, it has a low calorific value (v S R Krishna & K, 2018).





4.3 Summary

According to the numbers gathered, the engine performance of palm oil biodiesel demonstrates that its usage in diesel engines is extremely poor. The graph shows that, although the increase created is the same as pure diesel, the use of biodiesel is weaker than pure diesel in terms of performance characteristics. Pure diesel produces more horsepower and torque than biodiesel while having a lower specific brake than biodiesel. Based on the statistics, it can be determined that pure diesel is more cost effective to use than biodiesel owing to the usage of oil that lasts longer despite producing horse power and high torque.



4.4 Emission Analysis

The data from the experiment that was done completely on the effect of biodiesel emissions has been shown in tables 4.4, 4.5, and 4.6 where the percentage variations in NOx, CO₂, CO, and HC are seen.

Engine load	CO (%)	CO ₂	HC (1/x),ppm	$NO_X (1/x), ppm$
kW		(%)		
0	6.07	0.9	179	2
0.4	5.71	1.0	200	6
MALA	6.00	1.1	280	12

Table 4.4 Data effect of biodiesel emissions D100

Table 4.5 Data effect of biodiesel emissions B20

Engine load	CO (%)	CO ₂	HC (1/x),ppm	NO _X (1/x),ppm
kW		(%)		
با ملاف	5.01	2.00	55	16 بوم
0.4	3.92	2.50	70	18
UNIVERS	4.00	2.70 -	MAL/94 SIA N	IELAI21

Table 4.6 Data effect of biodiesel emissions B30

Engine load	CO (%)	CO ₂	HC (1/x),ppm	NO _X (1/x),ppm
kW		(%)		
0	3.43	3.00	43	22
0.4	0.73	3.20	45	24
1	1.73	3.30	49	26

4.4.1 Carbon monoxide (CO) emission

Figure 4.4 depicts the CO emissions from Palm oil and diesel mixtures as engine load varies. CO emissions were minimal at low and medium loads (for the test fuel samples), but increased gradually (at maximum load) as the engine load increased. This was caused by variations in the air-fuel input during the engine's various operating situations (Yaqoob et al., 2021). Furthermore, larger engine loads result in increased CO emissions because more gasoline is consumed and a greater number of fuel-rich zones with low O2 levels are produced (Yagoob et al., 2021). The CO emissions of the generated biodiesel mix (B20) were found to be quite close to those of diesel. This is due to the high concentration of oxygen in biodiesel, which promotes full burning (Abed et al., 2019). Even when all of the manufactured palm oil biodiesel blends were compared to diesel, all of the biodiesel blends reduced CO emissions. CO emissions were lowered by 17.4%, and 43.5% on average for B20, and B30, respectively. Furthermore, as the quantity of palm oil biodiesel in the blends grew, CO emissions decreased, with the impact being most obvious in B30 blends. As the proportion of palm oil biodiesel increases, the extra air ratio during combustion decreases. In compared to diesel, the cylinder has an excess of oxygen for combustion, which assists in the oxidation of many more carbon molecules. When compared to the other biodiesel blends tested, the B30 palm oil biodiesel mix produced the least amount of carbon monoxide. Furthermore, the resulting experimental result has similar outputs produced from earlier experimental outcomes (Bitire & Jen, 2022).



Figure 4.4 Variation of CO emission with engine load for palm oil biodiesel

4.4.2 Carbon dioxide (*CO*₂) emission

Figure 4.5 depicts the change of CO_2 emissions with engine load for diesel and biodiesel-diesel mixes. All test samples show an increasing trend in CO_2 emissions as engine load rises. However, studies have shown that increasing the biodiesel volume portion in diesel increases CO_2 emissions (Abed et al., 2019). CO_2 emissions have increased by 55.00%, and 70.00%, respectively, as compared to diesel. This is due to the high concentration of oxygen in biodiesel, which allows for a longer and more stable diffusion combustion phase (Abed et al., 2019). Because biodiesel contains numerous oxygen molecules, the additional oxygen present in the mixture facilitates full combustion. As a result, it contributes to the CO_2 production process between oxygen and carbon. However, sample D100 emits the least amount of CO_2 , whereas blend B30 emits the most (Bitire & Jen, 2022). This result we can conclude that same like what the others article result such as this article (Abed et al., 2019).



Figure 4.5 Variation of CO₂ ratio with engine load for palm oil biodiesel

4.4.3 Hydrocarbon (HC) emission

Figure 4.6 depicts the increase in HC emissions as engine load increases. The graph illustrates that the proportion of biodiesel raises overall HC emissions. Hydrocarbon emissions increased from starting load to full load in all blends. This is because there is less oxygen available for reaction when more fuel is pushed into the cylinder under higher stress (Yaqoob et al., 2021).

However, as compared to pure diesel, B20,and B30 reduced by 69.27%, and 75.98%, respectively. When compared to other test samples, B30 exhibits the lowest HC emissions. Because ester-based fuels have a higher cetane number than diesel, HC emissions decrease as the blend ratio increases from B20 to B30. Furthermore, shorter latency durations result in decreased HC emissions. Furthermore, when the biodiesel mix ratio grows, the intrinsic oxygen in the ester combined with the increased oxygen concentration (raising the quantity of palm oil biodiesel in the blend) results in improved combustion, resulting in lower HC emissions. The amount of HC emission measured in this experiment was found to be comparable to prior investigations (Bitire & Jen, 2022). This result has found similar compared to this (Bitire & Jen, 2022) article.



Figure 4.6 Variation of HC emission with engine load for palm oil biodiesel

4.4.4 Nitrogen oxides (NOx) emission

Figure 4.7 depicts the NOx emissions of the palm oil biodiesel combination at various load levels. The graph depicts the rise in NOx for all biodiesel blend percentages, including conventional diesel. This rise in NOx is quite harmful in general because it can generate acid rain, which can injure the skin if exposed. This is supported by the study that has been conducted (Yaqoob et al., 2021).

Whereas the generated biodiesel oil has flaws in its emissions. NOx emissions from palm oil biodiesel blends were found to be higher than pure diesel emissions at all loads. NOx emissions increased by 87.50%, and 90.90% on average for B20, and B30, respectively. This is due to the fact that NOx emissions from biodiesel mixes are heavily impacted by fuel characteristics, engine load, and oxygen concentration. The small increase in NOx emissions seen with the palm oil biodiesel mix can be attributed to the biodiesel fuel's high oxygen content (Abed et al., 2019). Furthermore, the biodiesel fuel utilised contains more unsaturated fatty acids, which result in a higher adiabatic flame temperature and increased NO emissions. The findings are consistent with those of other researchers who assert that biodiesel mixes release more NOx than conventional diesel fuel (Bitire & Jen, 2022).



Figure 4.7 Variation of NOx emission with engine load for palm oil biodiesel

4.5 Summary

Palm oil has been successfully converted into biodiesel. The statistics acquired lead to the conclusion that the engine power output for B20 and B30 mixtures is the same as for conventional diesel. As a result, B30 may be chosen as the best biodiesel oil among B20 due to its improved combustion, lower HC, and average percentage change in CO emissions when compared to conventional diesel and B20 palm oil biodiesel. In terms of CO₂ emissions, B30 palm oil biodiesel is the best because of the higher percentage, which allows for a longer and more stable diffusion combustion phase. As for the average percentage change in Nox emissions, it can be concluded that biodiesel palm oil B20 and B30 is very disappointing because it is higher compared to conventional diesel. The increase in NOx emission changes is very harmful to the environment because NOx gas is categorized as a harmful gas.



CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Following are some conclusions that may be drawn from the study's data and analysis:

- Pure palm oil biodiesel was created using the transesterification method and was mixed with pure diesel (D100) using an electromagnetic stirrer to make B20 and B30 biodiesel-diesel fuels. It is to ensure that the two types of oils were fully blended and completely combined in order to obtain the most accurate results.
- 2. The performance of B20 and B30 biodiesel fuel engines was compared using data from an engine dynamometer linked to a single cylinder fuel injection diesel engine, and the findings revealed that the B20 generated the most horsepower and torque at full load despite using a larger amount of fuel. Greater horsepower means quicker acceleration, whereas higher torque means the smallest feasible delay during the engine reaction phase. When it comes to brake specific fuel usage, B30 biodiesel fuel outperforms B20 biodiesel fuel and D100 pure diesel. This is because it has the lowest calorific value, requiring a greater amount of fuel to generate a high engine braking capability. Although pure diesel D100 is simpler to start a diesel engine and lasts longer than palm oil Biodiesel fuel, it can be said that palm oil Biodiesel fuel (B20 and B30) is still the best fuel to use in terms of engine performance.
- 3. Exhaust emissions of B20 and B30 biodiesel fuels were analyzed using data collected from a gas analyzer connected to the exhaust of a fuel injection single cylinder diesel engine, and the results showed that B30 produced the lowest CO emission due to the higher rate of complete combustion that combined the CO particle with the higher oxygen content contained in the biodiesel, resulting in higher CO_2 emission. B30 also created the lowest HC emission owing to the
greater cetane content of the biodiesel fuel, which also supports a better rate of full combustion by the biodiesel fuel. Nevertheless, B30 produced the greatest NOx emission that contributes to the biodiesel fuel. It is possible to state that B30 is the best fuel for usage in terms of exhaust pollution because of its lower CO emission, which results in greater CO_2 emissions and lower HC emissions.

5.2 **RECOMMENDATION**

For future recommendation, that are some suggestion that can be done, such as;

- 1. Testing biomixtures in a range of engine conditions is one area where improvement is suggested for the future. Examples include modern direct-injection diesel engines with common-rail injection systems that can be tested with an emission analyzer.
- 2. The use of a cutting-edge emissions analyzer also allows for the study of transient engine operation. Places where a wider range of emissions may be studied using this tool.
- 3. The adequate measuring methods should be used to examine the possibility of additional pollutants, such as N₂0, emerging from the interaction of ammonia and NOx. However, since N₂O is not a byproduct of combustion, neither pollution standards nor traditional gas analyzers take it into account, making this a particularly important area in which to exercise care.
- 4. Once the upstream NOx emission has been measured, a smart control system can be developed to optimise injection conditions such as flow rate and pressure.
- 5. Finally, research into the optimum material for storing biomixtures should focus on its metal content as well.

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APPENDICES

APPENDIX A Gant Chart PSM 1

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	PROGRESS	9-Mar	16-Mar	23-Mar	30-Mar	6-Apr	13-Apr	20-Apr	27-Apr	4-May	11-May	18- May	25-May	1-Jun	8-Jun	
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First week PSM Briefing about our presentation	100%							~								
Find the related material for our title project	100%									V.,						
Meeting with our supervisior	100%															
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Project Prsentation	100%															

FINAL REPORT SUBMISSION

APPENDIX B Gant chart PSM 2

