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Potential and Properties of Palm Diesel as Alternative Fuel for Automotive Engines

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Abstract *– This paper presents the potential, properties and test results of palm diesel as an alternative fuel for automotive engines. The palm diesel was tested with different blending ratio with diesel fuel as well as with antioxidant additive. Total three fuels were tested such as 100% diesel fuel, 20% palm diesel with 80% diesel fuel (B20); and B20 with 1% antioxidant additive. The pure diesel fuel was used for comparison purposes. A multi cylinder diesel engine was used in this investigation. The data presented are palm diesel production and potential status, physicochemical properties such as fuel standardization, engine brake power, fuel consumption and emissions results. It can be said that the palm diesel production, properties and test results have reached to a point as it is ready to be implemented in diesel engine. According to a stationary dynamometer-engine test, it is found that the 20% palm diesel with antioxidant additive shows better results such as less HC, CO and NOx emissions as compared to pure diesel fuel. The details test results including palm diesel price consideration have been presented with discussions.*

Keywords – Diesel engine, emissions, fuel standardization, palm diesel, performance.

1. INTRODUCTION

Biodiesel is a renewable fuel that can be produced from various sources such as vegetable oils, animal fats and used cooking oil. It can be used in its neat form, or as a blend with conventional diesel fuel, in diesel engines without any modifications. Since biodiesel is produced from renewable, it can reduce the use of petroleum based fuels and possibly lower the overall greenhouse gas emissions from the use of internal combustion engines.

Biodiesel is also chosen to replace petroleum diesel because of its benefits such as biodegradable nature, essentially no sulfur and aromatic contents, offers promise to reduce particulate and toxic emissions. It can also be an attractive fuel for use in environmentally sensitive applications such as industrial sector and public transport. Biodiesel when mixed with diesel fuel, in small quantities, also seems to improve the fuel lubricity, extend engine life and reduce fuel consumption [1]. This paper presents the latest status of palm diesel potential, properties and the test results obtained from a multi-cylinder diesel engine.

The Global Scenario of Biodiesel

In the global scene, the use of methyl esters as diesel fuels has been well acceptance especially in USA and European Union (EU). In fact, biodiesel made from rapeseed oil is already produced on a significant scale in Italy, France, Germany, Austria, Australia Sweden and many more countries. The Figure 1 shows production and capacity of biodiesel in various countries. Production capacity of biodiesel rose from about 75,000 tons in 1991 to about 3.5 million tons in 2004. New legislation and government incentives strongly support the use of biofuel particularly biodiesel that have been introduced. The EU Directive on the use of the biodiesel in transport sector is 2% of the total diesel consumption of about 160 million tons per year for 2005 and will be increased gradually to 5.75% by the year 2010 [2].

In US, biodiesel is registered as a fuel and fuel additive with the Environmental Protection Agency (EPA) and meets clean diesel standards established by the California Air Resources Board. Neat biodiesel has been designated as an alternative fuel by the Department of Energy and the US Department of Transportation. The estimated production capacity for 2004 was 500,000 tons.

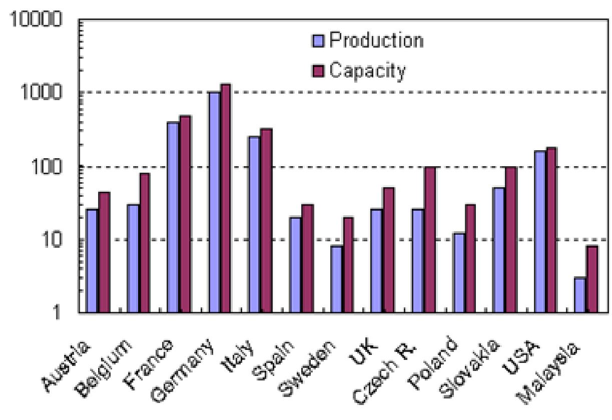

Fig.1. Biodiesel production and capacity in the world (1000 tons).

In Asia, Japan, Korea, China and Thailand have also expressed interest in biodiesel in the last few years. All of these developments underscore the environmental benefits in terms of reduction in green house gas emission, reduced dependence in the fossil fuel imports and positive impact on agriculture [3].

Palm Oil Production in the World

In year 2005, Malaysia and Indonesia produced 14.962 and 14.07 million metric tons of palm oil respectively which when combined is 86% of total palm oil production

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in the world. Table 1 shows major world producers of palm oil in the world.

In Malaysia, the increased in production came about by an increase in area planted. The area increased just over 200,000 hectares, almost all in East Malaysia (Sabah and Sarawak) as the more developed Peninsula has run out of land.

Table 1.Major world producers of palm oil:2000-2005 ('000 tons)

Country	2000	2001	2002	2003	2004	2005
Malaysia	10,842	11,804	11,909	13,355	13,976	14,962
Indonesia	7,050	8,080	9,370	10,300	11,400	14,070
Nigeria	740	770	775	785	790	800
Colombia	524	548	528	527	625	661
Cote d'l voire	278	205	240	240	270	-
Thailand	525	625	600	640	680	685
Papua New Guinea	336	329	316	326	350	310
Equator	218	228	241	247	250	-
Costa Rica	137	150	145	155	195	-
Honduras	97	122	126	140	144	-
Brazil	108	110	118	129	135	160
Venezuela	70	74	71	76	83	-
Guatemala	65	70	86	85	89	-
Others	5,873	883	901	898	966	1,826

Source: Oil World

Palm Diesel Production in Malaysia

Since 1980s, Malaysian Palm Oil Board (MPOB) in collaboration with the local oil giant "Petronas" has begun transesterification of crude palm oil into POD. It is now under design and building a 60,000-tons per annum palm diesel plant based on its previous 3,000 tons per annum pilot plant in the MPOB head quarters. In addition, there are three different plants available to produce two grades of palm diesel such as normal grade and winter grade. They can produce 60,000 tons normal grade and 30,000 tons winter grade per annum. Another four new plants are now under constructions, and they will be ready to produce 360,000 tons per annum by the end of year 2008. Some of these plants will produce three types of fuels: (1) Blending petroleum diesel with palm diesel as known as envo diesel; and (2) To convert palm oil into methyl ester as known as palm diesel which is two different grades such as normal grade and winter grade. All these fuel will be used as an alternative fuel. Malaysia produced about 15 million tons of crude palm oil in 2005 and the government is trying to convert over 500,000 tons into biodiesel. Currently, 10 percent of palm oil production has been allocated for biodiesel project. It will further stabilize the prices of palm oil in the international market and subsequently, contributes to the Malaysian palm oil industry [4] as well as partial replacement of diesel fuel. Consumption of diesel fuel was 4.84 billion liters and 5.32 billion liters in 2004 and 2005 respectively. For a trail purpose, more than 150 vehicles (bus, truck and lorry) are running on blending petroleum diesel with palm diesel to evaluate engine's noise, lube oil, emissions and performance characteristics. At present, Malaysia exports palm diesel to Korea, Germany and Japan.

World Biodiesel Standardization

Biodiesel is the term refers to methyl esters of long chain fatty acids derived from vegetable oils. The Fuel Standards Regulations 2001 under the Fuel Quality Standards Act 2000 define biodiesel as "a diesel fuel obtained by esterification of oil derived from plants or animals" [5]. It also can be used as a fuel in compression ignition engines without any modification.

Germany and EU have done biodiesel standard for rapeseed methyl ester and their biodiesel standard names are DIN E51606 and DIN EN 14214 respectively. The USA has produced biodiesel standard for soybean methyl ester. Japan and Korea have also produced biodiesel standards. The EU standard DIN EN 14214 is often used as the reference for other nations considering adoption of biodiesel standards although the USA has its own biodiesel standard.

In Malaysia, biodiesel are derived from palm oil by methanol transesterification process. Palm biodiesel are chosen to replace petroleum diesel because it will reduce in emissions generated when using this biodegradable and low toxicity fuel. Currently, Malaysia has produced two types of palm biodiesel. The normal palm biodiesel (normal grade) with pour point of 15ºC can only be used in tropical countries while the low pour point biodiesel (winter grade) (-21ºC to 0ºC) can be used in low temperature countries to meet the seasonal pour point requirements (summer grade, 0ºC; spring and autumn grades, -10ºC and winter grade, -20ºC. The world standard comparisons are shown at the Table 2.

Blended Biodiesel – Fuel Preparation

The analysis and the preparation of tested fuels were conducted at the Engine Tribology Laboratory, Department of Mechanical Engineering, University of Malaya. A total of three fuels were selected for this investigation. The test fuels chosen are (1) 100% conventional diesel fuel (B0) supplied by Malaysian petroleum company (Petronas), (2) B20 as 20% POD blended with 80% B0 and (3) B20+1% as B20 with 1% additive. The blending process was done using mechanical stirrer under room temperature with stirring speed of 2000 rpm.

A study was conducted by Masjuki et al. [6] on the effect of oxidized and non-oxidized palm oil methyl ester on the stability properties during time of storage (total storage time was 7 weeks). The results were presented in terms of viscosity, total acid number (TAN) and various oxidations such as nitration, sulfation, water and glycol. It is found that after four weeks POME and B20 oxidizes that affect on lubrication properties such as increases viscosity, TAN number and various oxidations. Hence, degrade the lubricant quality. In this investigation, an additive was added with B20 fuel to resist oxidation as well as increases fuel conversion to mechanical energy.

Additive

Nonyl Phenoxy Acetic Acid (NPAA) was used as additive in biodiesel fuel. The viscosity, melting point, density and flash point of NPAA are 1750 $mm^2 s^{-1}$ (at 40°C), 0°C, 1.03 g cc^{-1} and 130°C respectively. Biodiesel is a vegetable oil based fuel that will produces more numbers of oxidations as compared to diesel fuel before converting into thermal energy. This additive is claiming to reduce oxidations level and hence, fuel conversion energy will increase.

Table 2. Standardization of biodiesel.

Country		Germany [7]	EU [7]	USA[8]	Korea [9]	Malaysia [3]	
Standard/ Specification		DIN E 51606	EN 14214	ASTM D6751	B20	B100	LPPP*
Date		Sep-97	July 2003	10-Jan-02	30-Sept-04	Aug-2005	
Application		FAME	FAME	FAME	FAME	FAME	FAME
Density 15°C	g/cm3	0.875-0.90	0.86-0.90	0.80-0.90	0.86-0.90	0.8783	0.87-0.9
Viscosity 40°C	mm2/s	3.5-5.0	3.5-5.0	1.9-6.0	1.9-5.5	4.415	4-5
Distillation 95%	ºC	-	-	≤ 360	-	-	-
Flashpoint	ºC	> 100	≥120	> 130	>120	182	150-200
Cloud point	ºC	-	-	-	-	15.2	-18-0
CFPP	ºC	0/-10/-20	-	-	-	15	-18-3
Pour point	ºC	-	-	-	-	15	-21-0
Sulfur	% mass	< 0.01	≤0.0010	-	<0.001	<0.001	<0.001
CCR 100%	% mass	< 0.05	-	<0.05	-	-	-
10% dist.resid.	% mass		≤0.30	-	<0.5	0.02	0.025
Sulfated ash	% mass	< 0.03	≤0.20	0.02	<0.02	<0.01	<0.01
(Oxid) Ash	% mass	-	-	-	<0.02	-	-
Water and sediment	mg/kg	<300	≤500	<500	<500	<500	<500
Oxidation Stability	hrs/110°C		-		>6	-	-
Total contam.	mg/kg	<20	≤24	-	<24	-	-
Cu-Corros.	3h/50°C	1	Class 1	< No.3	1	1a	1a
Cetane No.	-	> 49	≥51	>47	-	-	-
Acid value	mgKOH/g	< 0.5	≤0.50	<0.80	-	0.08	<0.3
Methanol	% mass	<0.3	≤0.20	-	<0.2	<0.2	<0.2
Ester content	% mass	-	≥96.5	-	>96.5	98.5	98-99.5
Monoglycides	% mass	< 0.8	≤0.80	-	<0.8	<0.4	<0.4
Diglyceride	% mass	< 0.4	≤0.20	-	<0.2	<0.2	<0.2
Triglyceride	% mass	< 0.4	≤0.20	-	<0.2	<0.1	<0.1
Free glycerol	% mass	< 0.02	≤0.020	0.02	<0.02	<0.01	<0.01
Total glycerol	% mass	< 0.25	≤0.25	0.24	<0.25	<0.01	<0.01
Iodine No.	-	< 115	≤120	-	-	58.3	53-59
C18:3 and high. unsat. acids	% mass	-	-	-	< 1	<0.1	<0.1
Phosphorous	mg/kg	<10	≤10	<10	<10	-	-
Alcaline met. (Na, K)	mg/kg	<5	≤5	-	<5	-	-
Linolinec acid	% mass	-	-	-	<12	<0.5	<0.5
Lubricity 60°C	µm	-	-	-	<460	-	-

* LPPP = Low Pour Point Palm Biodiesel

2. THE EXPERIMENTAL SET-UP AND PROCEDURE

The specifications of the indirect injection (IDI) diesel engine are shown in Table 3. The dynamometer instrumentation used in this investigation was fully equipped in accordance with SAE standard J1349 JUN90. A variable speed range of 1000 rpm-4000 rpm with half-throttle setting was selected for performance test such as to measure brake power and SFC. The emission test was done with constant 50 Nm load and at constant 2250 rpm engine speed. The same test procedure and practice were followed for all the fuels. A Bosch gas analyzer model ETT 008.36 was used to measure HC and CO emissions. A Bacharach model CA300NSX analyzer (Standard version, k-type probe) was used to measure NOx concentration in vppm (parts per million by volume).

Table 3. Specification of diesel engine being used

Engine	Isuzu
Model	4FB1
Type	Water-cooled, 4 strokes
Combustion	Indirect injection (IDI)
Number of cylinders	4
Bore x Stroke	84 x 82 mm
Displacement	1817 cc
Compression ratio	21:1
Nominal rated power	39 kW/5000 rpm
Maximum torque speed	1800 – 3000 rpm
Dimension (LxWxH)	700 x 560 x 635 (mm)
Cooling system	Pressurized circulation

3. RESULTS AND DISCUSSION

All the tests and data analysis were performed for different fuels in the Tribology Laboratory, Department of Mechanical Engineering, University of Malaya. The data were used to evaluate differences in these fuels and to serve as a basis for comparison of the blended fuels.

Brake Power Output

The results of brake power output from turbocharged diesel engine for every fuel test are shown Figure 2. It can be seen that fuel B20+1% produces higher brake power over the entire speed range in comparison to other fuels. It was found that fuel B20+1% produces an average of 11.82 kW brake power over the entire speed range followed by B20 (11.38 kW) and B0 (11.50 kW). It was calculated that fuel B20+1% produced 2.93% higher brake power than fuel B20 which is the effect of 1% additive in fuel B20. The maximum brake power obtained at 2500 rpm was 12.28 kW from B20+1% fuel followed by 11.93 kW (B20) and11.8 kW (B0) fuels. This can be attributed to the effect of fuel additive in B20 blends which influences the conversion of thermal energy to work or increases the fuel conversion efficiency by improving the fuel ignition and combustion quality (compete combustion).

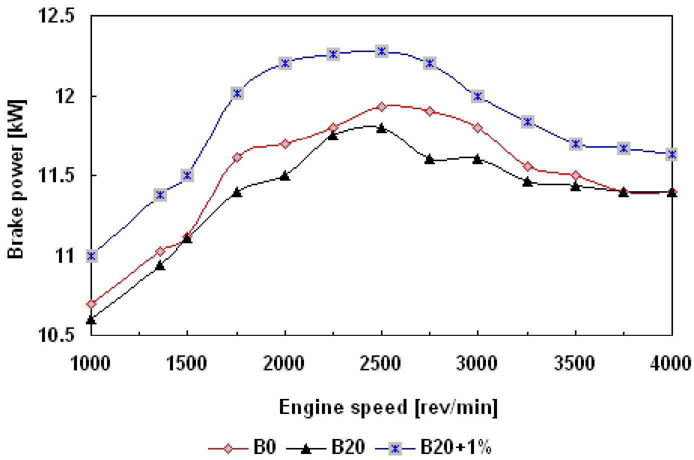

Fig. 2. Brake power output vs. engine speed

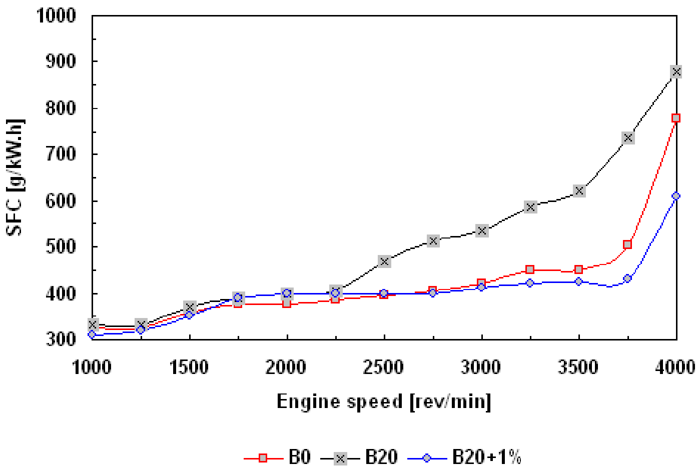

Fig. 3. Specific fuel consumption vs. engine speed

Specific Fuel Consumption

Figure 3 shows specific fuel consumption (SFC) for all the fuels. It can be seen that the behavior of fuels B20 and B20+1% are similar as B0 fuel until the engine speed of 2250 rpm, after that fuel consumption of B20 increases. Fuel B20+1% shows a similar SFC as B0 fuel until engine speed of 3500 rpm. It can be explained that 1% additive in fuel B20 produced fuel conversion as similar as B0 fuel and it even showed low fuel consumption compared to B0 fuel after engine speed of 3500 rpm. The lowest SFC was obtained from B20+1% fuel followed by B0 and B20 fuels. The average SFC value all over the speed range are 405 g/kW.h, 426.69 g/kW.h and 505.38 g/kW.h for B20+1%, B0 and B20 fuels, respectively.

Oxides of Nitrogen (NOx) Emission

The effect of additive in biodiesel blended fuel on Nitrogen Oxide (NOx) concentration is shown in Figure 4. It was found that the NOx concentration decreases with B20+1% fuel as 92 ppm which is lower than B20 and B0 fuels. It can be examined that NOx was produced from high combustion temperature that produced from burning of fuel. Hence, individual fuels combustion temperature is responsible to produce NOx concentration. It can be revealed from test results that 1% additive was helpful to reduce combustion temperature with keeping high fuel conversion as compared to B20 fuel. Hence, additive is effective in B20 fuel.

Carbon Monoxide (CO) Emission

Carbon monoxide is formed during the combustion process with rich air-fuel mixtures regions and when there is insufficient oxygen to fully burn all the carbon in the fuel to CO_2. However, normally a diesel engine uses more oxygen (excessive air) to burn fuel which has a little effect on CO emissions. Since the operating conditions are exclusively lean, the CO concentration value for all the fuels is less than 1% as shown in Figure 5. It is found that among all the fuels, fuel B20+1% produces lowest level of CO emissions which is 0.1% followed by B20 (0.2%) and B0 (0.35%). It can be explained that 1% additive in biodiesel blended fuel produces complete combustion as compared to B0 fuel, (for details see Figure 5).

Hydrocarbon (HC) Emission

Figure 6 shows HC emissions for all the fuels. It is found that fuel B20+1% produces lowest HC emission (29 ppm) followed by B20 (34 ppm) and B0 (41ppm). The difference between B20 and B20+1% is 5 ppm, revealed that fuel B20+1% produces better combustion than fuel B20 fuel.

Exhaust Temperature

Figure 7 shows the effects of biodiesel blended fuels with and without additive on exhaust temperature of an indirect injection turbocharged-diesel engine. The trends of exhaust temperature shown for all of fuel tests were similar. However, for biodiesel blended fuels with additive, it produced lower exhaust temperatures as compared to B0 fuel. The presence of additive maintains combustion temperature through increasing fuel thermal conversion efficiency.

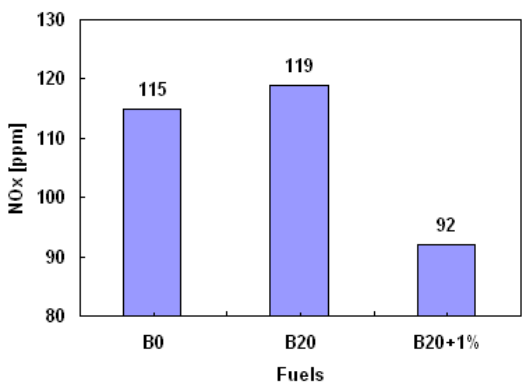

Fig. 4. NOx emission at constant load of 50 Nm and engine speed 2250 rpm

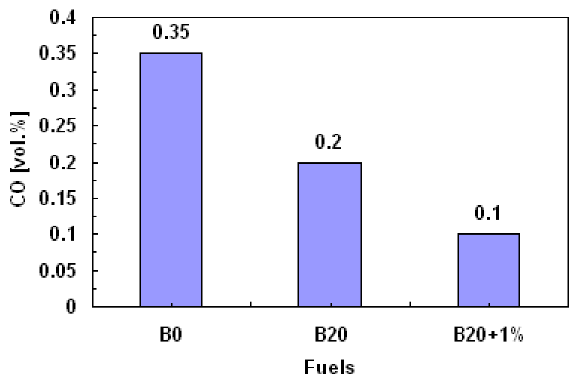

Fig. 5. CO at constant load of 50 Nm and engine speed 2250 rpm

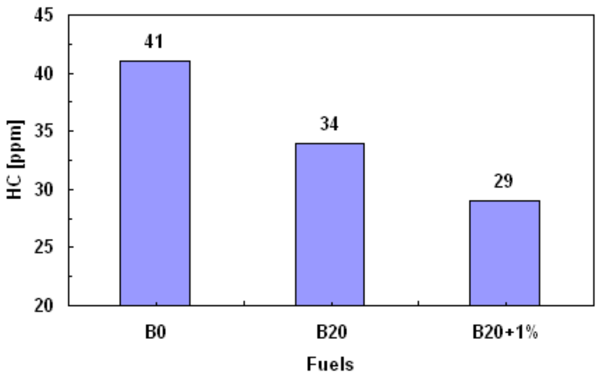

Fig.6. HC emission at constant load of 50 Nm and engine speed 2250 rpm

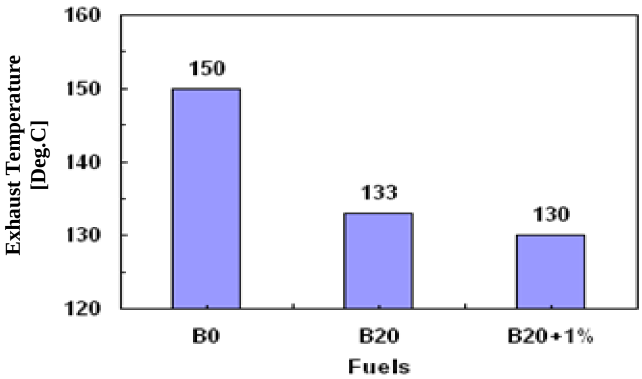

Fig.7. Exhaust temperature at constant load of 50 Nm and engine speed 2250 rpm

4. CONCLUSIONS

The major conclusions in this investigation can be drawn as follow:

1. Biodiesel production including palm diesel increases worldwide.
2. Palm diesel properties are comparable to other biodiesels such as rapeseed and soybean.
3. Palm diesel with additive (B20+1%) produces higher brake power and lower SFC compared to B0 and B20 fuels.
4. Palm diesel with additive (B20+1%) reduces NOx, CO, HC emissions and exhaust temperature compared to other fuels.

Hence, additive is effective in B20 fuel as well as fuel B20+1% and is suitable to be used in diesel engine.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Sulaiman Bin Arifin for technical assistance provided; Ministry of Science, Technology and Innovation Malaysia for Research Grant and University of Malaya which made this study possible.

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APPENDIX

Currently in Malaysia, the commercial selling prices of diesel fuel and palm oil are US$ 0.47 and US$ 0.50, respectively. The production cost of palm diesel (from palm oil) is about US$ 1.30 per liter which is higher that diesel fuel. At present the palm diesel is not being commercially sold in Malaysia, it is being exported abroad.