

Biofuel from Waste Palm Oil – An Analysis of its Properties and Comparisons with Other Biofuels

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Abstract: If the agricultural products market is limited and much of agricultural land is not utilized as is the case in many countries in the world at present, then agriculture should be directed to the production of new alternative products. The land can be used to produce non-food products including biofuels for the domestic energy market to diminish imports. Much research has been conducted on biofuels over the last 20 years. At present, concern about environmental regulations, green house gases and fossil fuel reservation (including natural) have been the major reasons to look for alternative fuels that come from renewable resources. A significant level in terms of physico-chemical properties of biofuel has been obtained mostly from methyl ester of food based vegetable oils; it is now the issue to be concerned about human food oil versus biofuel production.

This paper presents the experimental results carried out to evaluate performance and exhaust emissions of a diesel engine operated on "Envo Diesel" which consists of 5% palm oil and 95% ordinary diesel fuel (as P5). The Envo diesel is a policy of Malaysian government that emphasises on usage of waste palm oil with diesel fuel without esterification. This investigation also includes a benchmarking study with 5% coconut oil with 95% diesel fuel (as C5). However, all the results have been compared with pure diesel fuel (B0).

The results show that fuels P5 and C5 reduce brake power 1.2% and 0.7% respectively as compared to B0. However, both the fuels P5 and C5 reduce exhaust emissions such as reduce HC, smoke, CO and NOx concentration. The paper contains the test results, properties of P5 and C5 biofuel and comparison with other biofuels that obtained from various vegetable oils. The results of this investigation will be used to find compatible lubricant/additive for biofuel operated engines.

Key words: Biofuel, Renewable energy, Engine performance, Envo Diesel, Coconut oil.

INTRODUCTION and LITERATURE REVIEW

Recently, the use of diesel engines has increased rapidly because of their low fuel consumption and high efficiencies. Nowadays, diesel engines are used in transportation, power plant generation equipment, construction and industrial activities. These wide fields of the usage lead to increase the demand for petroleum fuel. The world is presently confronted with crises of fossil fuel depletion and environmental degradation.

The present energy scenario has stimulated active research interest in non-petroleum, renewable, and non-polluting fuels. The world reserves of primary energy and raw materials are, obviously, limited. According to an estimate, the reserves will last for 218 years for coal, 41 years for oil, and 63 years for natural gas, under a business-as-usual scenario (Agarwal 2007).

The depletion of world petroleum reserves and increasing of demand also causes rise in fuel prices. The prices of crude oil keep rising and fluctuating on a

daily basis which are at near record levels and are stabilizing at about US\$140 per barrel now at Malaysia. This necessitates developing and commercializing unconventional fuel from natural sources. This may well be the main reason behind the growing interest for unconventional bio-energy sources and fuels around the world especially developing countries, which are striving hard to offset the oil monopoly.

This study concentrates on assessing the viability of using alternative fuels in the existing internal combustion engines. In Malaysia, many researches are carried out on palm oil to produce biofuel or biodiesel as an alternative fuel. Malaysia has become the biggest palm oil producer country in the world followed by Indonesia. Recently, Malaysian Palm Oil Board (MPOB) has been produces the P5 palm oil-based biofuel called "Envo Diesel" for local use. After palm oil, coconut oil is the next potential oil that can be produced as biofuel because of its high amount of

oxygen contents that enhance the combustion process.

The objective of this study is to carry out an experimental investigation of the performance and the exhaust emission characteristics of a diesel engine fueled with Envo Diesel and coconut oil blends and compared them with ordinary diesel fuel.

EXPERIMENTAL SETUP AND PROCEDURES

The schematic of the experimental setup for used engine test bed can be seen in Fig.1.

A TOYOTA 2L series diesel engine was selected for this investigation. The engine is type 2L, 53.6 kW capacities, fixed speed (4000 rpm). It is water-cooled, indirect diesel injection engine. The specifications of engine are shown in Table 1.

Table 1. Specification of Toyota Hilux Engine

Engine	TOYOTA
Model	2L
Type	Four strokes, water-cooled
Combustion	IDI, naturally aspirated
Number of cylinder	4
Bore x Stroke	92 x 92mm
Displacement	2.4 L (2446 cc)
Compression ratio	22.3 :1
Combustion chamber	Swirl chamber
Nozzle type	Throttle
Cooling system	Pressurized circulation
Continuous power output	53.6 kW at 4000 rpm
Torque	155.9 Nm at 2200 RPM

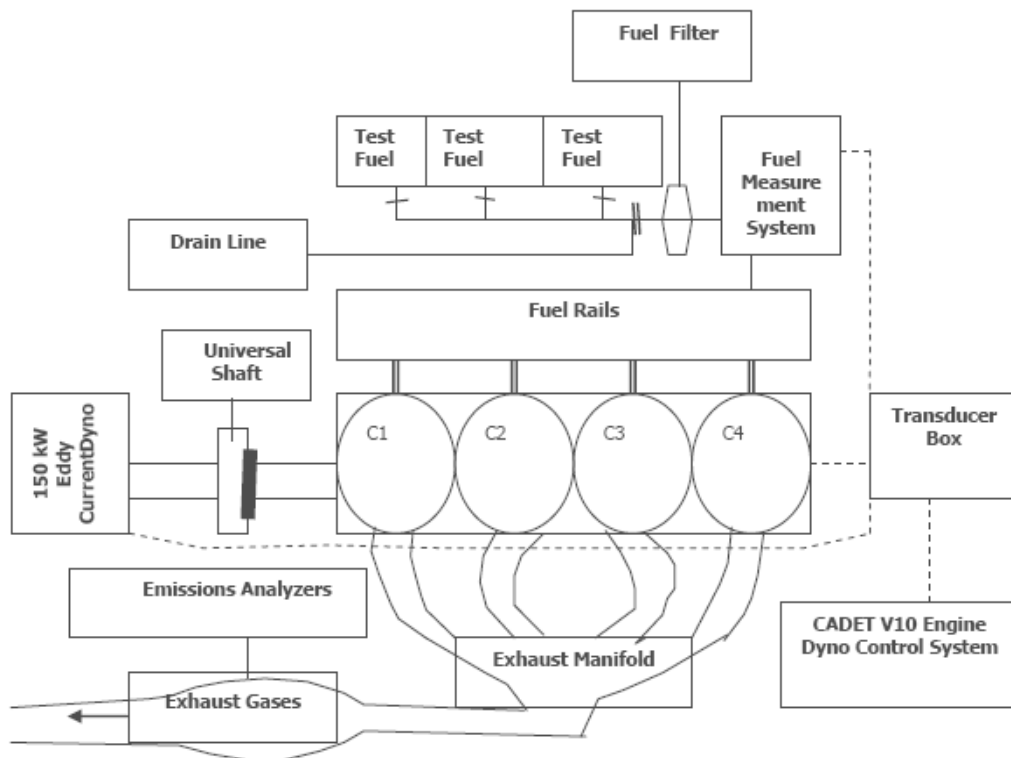


Figure 1. Schematic Diagram of Engine Test Bed.

Exhaust gas analyzer

Horiba exhaust gas analyzer was used to measure HC, CO,CO₂ and NO_x emissions. The analyzer was interfaced with engine controlled software so that all the data from emission analyzer and engine are logged at same time. The Hartridge smoke meter was used to measure smoke emission.

Test fuel

The analysis and the preparation of test fuels were conducted at the Engine Tribology Laboratory, Department of Mechanical Engineering, University of Malaya. A total of three test fuels were selected for this investigation. The test fuels chosen are (1) 100% conventional diesel fuel (B0) supplied by Malaysian

petroleum company (Petronas), (2) P5 as 5% palm olein and 95% B0. It can be mentioned that fuel P5 is known as "Envo diesel" in Malaysia. (3) C5 as 5% coconut oil and 95% B0. The fuel C5 is being selected to be compared with Envo diesel. Details about Envo diesel can be seen in below-

Envo Diesel (Direct blending)

Envo Diesel consists of 5 percent processed palm oil commonly known as cooking oil and 95 percent conventional diesel fuel. The Malaysian Government has decided on the Envo Diesel for the local market because production cost of palm olein is RM1 per litre cheaper than ethyl ester. The Envo Diesel will be implemented in stages starting with vehicles of selected governmental agencies and then moving on the public use. The Malaysian palm oil board (MPOB) is using the blends of processed palm oil with petroleum diesel to produce Envo Diesel. The advantages of envo diesel are:

- (a) No engine modification is required.
- (b) Results in terms of engine performance, fuel consumption, exhaust emissions, repair and maintenance are acceptable.

Fuel properties test

The main properties of fuel tested such as calorific value, viscosity, specific density and flash point have been tested through standard method. The ordinary diesel fuel properties are compared with blended fuels.

Heat calorific value: Oxygen Bomb Calorimeter was used to obtain the heating value of each fuel. The sample was ignited and burned in the combustion chamber in the presence of 20 bar of oxygen, and the

energy released is transferred to the surrounding water. The energy contain in the fuel was calculated on the basis of the conservation of energy principle by measuring the temperature rise of the water.

Mass of fluid x Caloric value = (Mass of water + water equivalent of bomb) x Corrected temperature rise x specific heat capacity of water.

Viscosity: Automatic viscometer was used for determining the kinematic viscosity of fuels. It provides a measure of the time required for a volume of fuels to flow under gravity through a calibrated glass capillary tube.

Specific gravity: Model DMA 4500/5000 specific gravity concentration meter was used to obtain the specific density value of tested fuels. The fuels density is measure at 15°C in g/cm³.

Flash point: Flash Point Tester HFP 380 Pensky Martens was used to measure the flash point value of each tested fuels. The flash point is determined by heating the fuel in a small enclosed chamber until the vapors ignite when a small flame is passed over the surface of the fuel. The temperature of the fuel at this point is the flash point.

The test fuel compositions and physicochemical properties can be seen in Table 2 and Table 3 respectively.

Table 2. Test Fuel Compositions

Fuel	Compositions
B0	100% diesel fuel
P5 (Envo diesel)	5% palm olein and 95% B0.
C5	5% coconut oil and 95% B0.

RESULTS AND DISCUSSION

Table 3. Physicochemical properties of fuels.

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Country			Germany	USA	Malaysia			
Properties/Fuels			Rape seed methyl ester	Soy bean methyl ester	Palm oil methyl ester	Envo diesel (P5)	C5	B0
1.	Density 15°C	g cm ⁻³	0.875-0.90	0.80-0.90	0.8783	0.827	0.827	0.82
2.	Viscosity 40°C	mm ² s ⁻¹	3.5-5.0	1.9-6.0	4.415	4.15	3.90	3.55
3.	Distillation 95%	°C	-	≤ 360	-	-	-	-
4.	Flash point	°C	> 100	> 130	182	>140	> 140	98
5.	High calorific value	MJ/kg	-	-	39.21	42.5	42.6	43

From physicochemical test results, it is found that, the C5 has better heating value than P5. The higher heating value contributes more power output after burning the fuel in the engine cylinder. The heating values of both the P5 and C5 are slightly lower as compared to B0. From viscosity test result, it is found that the C5 fuel has lower viscosity than P5. Lower viscosity of a fuel contributes better atomization. However, the viscosity of both P5 and C5 are slightly higher than B0. Similar differences of all other properties along with biodiesel properties from other countries can be seen in Table 3.

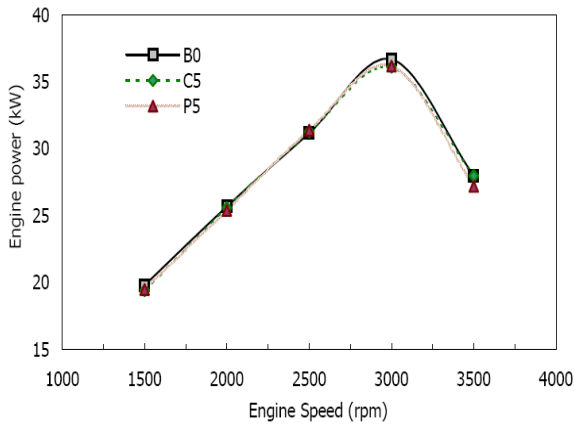


Figure 2. Engine Brake Power Vs Speed At 85% Throttle.

Engine brake power versus speed at constant 85% throttle setting can be seen in Fig.2. It can be seen that brake power increases with increasing engine speed until 3000 rpm and then power starts to drop due to the effect of higher frictional force. The maximum brake power obtained by B0, C5 and P5 are 36.7 kW, 36.10 kW and 36.20 kW respectively at 3000 rpm. The lower brake power by C5 and P5 as compared to B0 is mainly due to their respective lower heating values. The average brake power all over the speed range is found as 28.28 kW, 28.08 kW and 27.94 kW by B0, C5 and P5 respectively.

The variation of exhaust gas temperatures of all the fuels are shown in Fig. 3. Exhaust gas temperatures of the blended fuels are lower than those of the diesel fuel due to the lower heating value. However, their differences are small such as an average of all over the speed range 0.77% and 0.8% lower by C5 and P5 respectively.

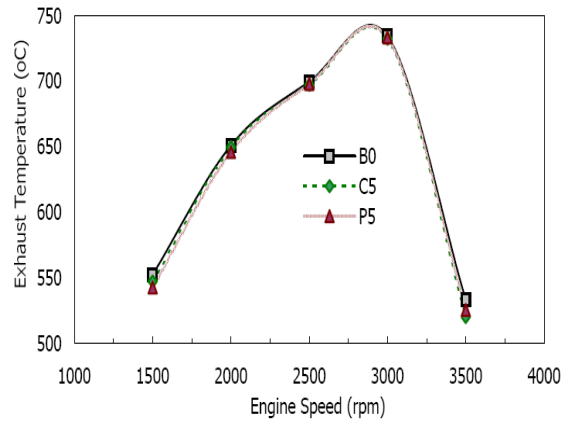


Figure 3. Exhaust Temperature Vs Speed At 85% Throttle.

The highest temperatures are found at 3000 rpm for all the fuels such as 735 °C, 732.5 °C and 733.6 °C by B0, C5 and P5 respectively.

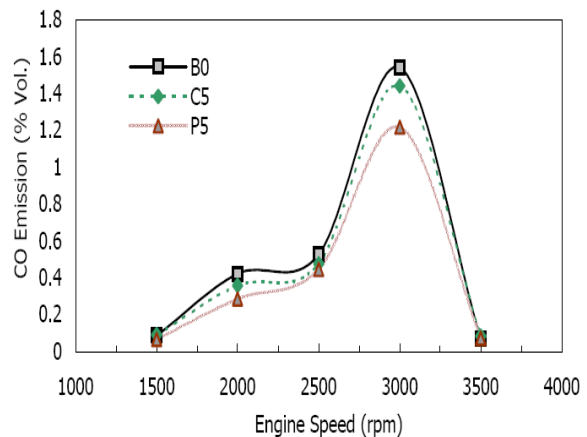


Figure 4. CO Emissions Vs Engine Speed At 85% Throttle.

As diesel engine operates with an overall lean mixture, their CO emissions are normally lower than gasoline engines. Carbon monoxide (CO) is a toxic gas formed by the results from incomplete combustion. Emissions of CO are greatly dependent on the air-fuel ratio relative to the stoichiometric proportions. The CO emission depends on many parameters such as air-fuel ratio and fuel combustion performance into the engine cylinder. The CO emission versus engine speed is shown in Fig.4. The maximum value of CO emission is found at 3000 rpm such as 1.54%, 1.44% and 1.21% for B0, C5 and P5

respectively. The lowest CO emission is found from envo diesel P5, followed by C5 and B0. On average all over the speed range, C5 and P5 reduce CO emission by 7.3% and 21% respectively.

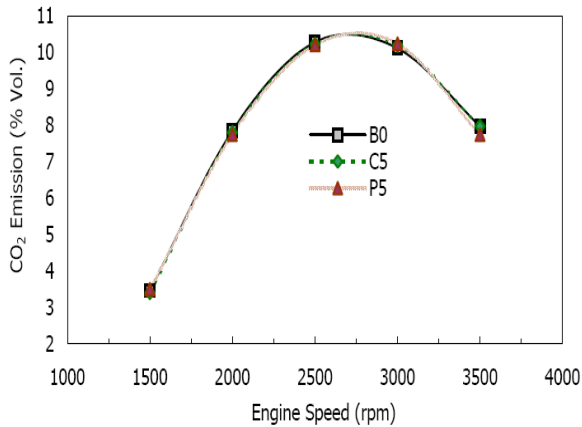


Figure 5. CO₂ Emissions Vs Engine Speed At 85% Throttle.

The CO₂ emissions of different fuels are shown in Fig.5. Increasing CO₂ emission means better combustion phenomena. The maximum CO₂ are found between 2500 rpm to 3000 rpm due to better combustion at the current throttle-speed position. The maximum CO₂ emission is found at 3000 rpm for all the fuels as shows 10.12%, 10.19% and 10.25% by B0, C5 and P5 respectively. The envo diesel produces more CO₂ than C5 and B0 fuels which means better combustion and it is proven since P5 produces lowest CO emission (Fig.4.)

Unburned hydrocarbons (HC) are the results of fuel incomplete combustion. Similar to carbon monoxide, unburned hydrocarbons result from flame quenching in crevice regions and at cylinder walls. Other causes of unburned hydrocarbons are running engine on too rich fuel air ratio with insufficient oxygen and the incomplete combustion of lube oil. Another cause is the oil film around the cylinder absorbs hydrocarbons, preventing them from burning, and then releases them into the exhaust gas. Also misfire admits hydrocarbons into the exhaust. It can be seen (in Fig. 6) that the

lowest level of HC is produced by Envodiesel P5 followed by C5 and B0. The maximum difference is found at 3000 rpm such as 21.8 ppm, 19.8 ppm and 14.9 ppm by B0, C5 and P5 respectively. However, all

over the test cycle, it is found that C5 and P5 reduce HC emission by 5.5% and 18% respectively as compared to B0 fuel. Now, based on CO, CO₂ and HC emissions, it can be confirmed that envo diesel P5 produce better combustion than C5 and B0 fuels.

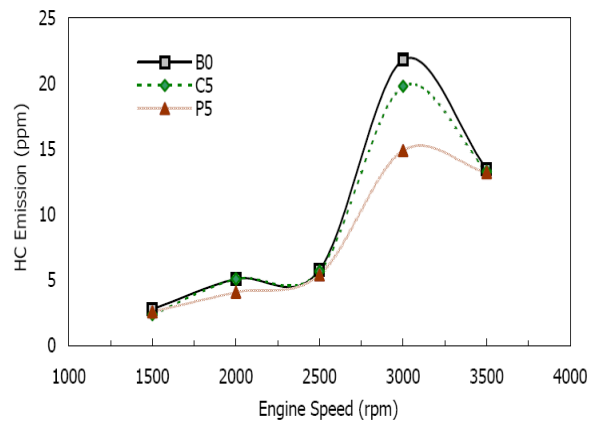


Figure 6. HC Emission Vs Engine Speed At 85% Throttle.

Oxides of nitrogen (NOx) emission is shown in Fig. 7. The NOx emission is strongly related to lean fuel with high cylinder temperature or high peak combustion temperature. A fuel with high heat release rate at premix or rapid combustion phase and lower heat release rate at mixing—controlled combustion phase (Masjuki et al. 2000) will produce NOx emission.

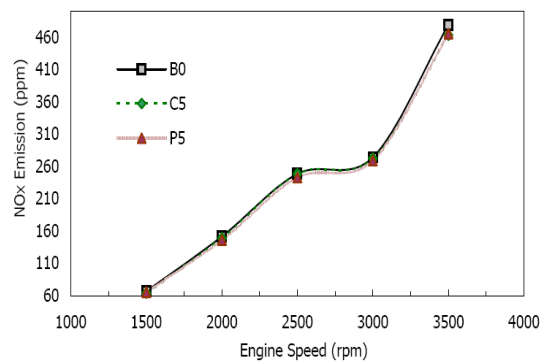


Figure 7. Nox Emission Vs Engine Speed At 85% Throttle.

It can be seen that NOx increases with increasing engine speed due to increasing combustion temperature into engine cylinder. The maximum NOx

is found at 3500 rpm such as 478.7 ppm, 462.7 ppm and 465 ppm by B0, C5 and P5 respectively. However, on average all over the speed range, C5 and P5 reduce NOx emission by 2% and 2.50% respectively as compared to B0 fuel.

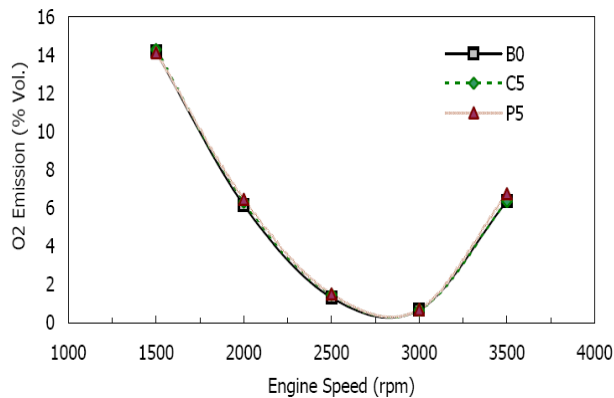


Figure 8. O₂ Concentration Vs Engine Speed At 85% Throttle.

The O₂ emissions of different fuels from the engine are shown in Fig.8. Increasing engine speed decreases O₂ concentration due to better combustion. At 3000 rpm, the O₂ concentration was lower as 0.7%, 0.68% and 0.71% for B0, C5 and P5 respectively. Fuels C5 and P5 show higher O₂ due to contain O₂ in pure coconut oil and palm oil as compared to B0. On average, all over the speed range, C5 and P5 produce 1.30% and 2.90% higher O₂ as compared to B0 fuel.

Smoke is a suspension in air (aerosol) of small particles resulting from incomplete combustion of a fuel. It is commonly an unwanted by-product of fuel combustion. Smoke produces from incomplete combustion of fuel resulting from fuel cooling effect or fuel air mixing problem etc. The relative smoke emission is shown in Fig.9. It is found that the lowest smoke produces by P5 fuel followed by C5 and B0 fuels. This proves that fuel envo diesel or P5 produces complete combustion as compared to C5 and B0 fuels. On average all over the speed range, the C5 and P5 fuels show 1.75% and 3.30% lower smoke opacity than B0 fuel.

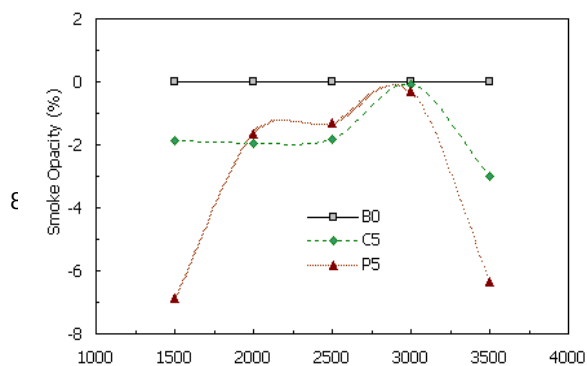


Figure 9. Smoke Emission Vs Engine speed At 85% Throttle.

CONCLUSIONS

The following conclusions may be drawn from present investigation such as –

- (1) Envo diesel (P5) produces 1.2% lower brake power as compared to diesel fuel B0.
- (2) Envo diesel (P5) shows better emission results such as lower CO, HC, NOx and smoke emissions as compared to C5 and B0 fuels.

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