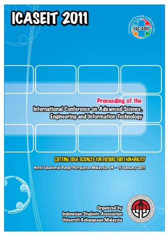
Proceeding of the International Conference on Advanced Science, Engineering and Information Technology 2011
Hotel Equatorial Bangi-Putrajaya, Malaysia, 14 - 15 January 2011
ISBN 978-983-42366-4-9



Performance of Untreated Waste Cooking Oil Blends in a Diesel Engine

Md Isa Ali, Shahrir Abdullah and Taib Iskandar Mohamad

Department of Mechanical and Material Engineering, National University of Malaysia
Bangi, Selangor, 43650 Malaysia
Tel.:+6012-9204859, E-mail: mdisa@utem.edu.my

Abstract*- Untreated waste cooking oil (UWCO) is not a feasible diesel fuel. The major problems in engine operation are reported mainly due to UWCO's high viscosity. To use UWCO's in diesel engine without modification, it is necessary to make sure that the oils properties must be similar to diesel fuel. In this study, UWCO that has been used several times for frying purposes is investigated for the utilization as an alternative fuel for diesel engines. In order to reduce the viscosity, the UWCO were blend with diesel. Two various blends of UWCO and diesel were prepared and its important properties such as viscosity, density, calorific value and flash point were evaluated and compared with that of diesel. The blends were then tested in a direct injection diesel engine in 10% and 30% v/v blends with a reference diesel fuel. Tests were performed under a set of engine operating conditions. It was found that blending UWCO with diesel reduces the viscosity. Blending of UWCO with diesel has been shown to be an effective method to reduce engine problems associated with the high viscosity of UWCO. The experimental results also show that the basic engine performance such as power output and fuel consumptions are comparable to diesel and the emissions of CO and NOx from the UWCO/diesel blends were also found slightly higher than that of diesel fuel.

***Keywords*- alternative fuel, waste cooking oil, renewable energy.**

I. INTRODUCTION

Nowadays, most of the waste cooking oil (WCO) is poured into the sewer system of the cities. This practise contributes to the pollution of rivers, lakes, seas and underground water, which is very harmful for environment and human health [1]. Only a small amount of the waste cooking oil is properly collected and recycled. In this situation the WCO may be an alternative option to be used as diesel substitute in diesel engines. Most of the WCO are from vegetable oils that are normally used for cooking or food frying purposes. These organic seed oil such as palm, coconut, soybean, rapeseed, safflower and their esters are considered as viable biofuels for diesel engines. They are renewable, nontoxic, biodegradable and their properties are comparable with diesel.

Many researchers have shown that these organic seed oil can be used as diesel substitute. However these biofuels presents several problems when compared with diesel due to their high viscosity and poor volatility. The high viscosity of these biofuels deteriorates the atomization, evaporation and their fuel mixture formation characteristics leading to improper combustion and higher smoke emissions. It creates operational problems such as difficulty in engine starting, unreliable ignition and decrease the thermal efficiency [2]. In long term use, these fuels might caused carbon deposits, ring sticking, fuel pump failure, etc. [3]. The literature also shows that a large amount works have done into evaluating the conversion the WCO to biodiesel [4]-[7]. The use of biodiesel as fuel for compression ignition engines has many environmental advantages; however, the production of biodiesel involves the use of a toxic, flammable liquid methanol and caustic compounds like sodium hydroxide or potassium hydroxide. It also presents several problems when compared with petroleum diesel such as low temperature properties, greater emissions of some oxygenated hydrocarbons and higher production cost.

There are some other methods to reduce the viscosity of vegetable oils. Fuel blending is one of the methods. It has the advantages of improving the use of vegetable oils with minimal processing and economic.

WCO used in industrial or household frying undergo degradation by thermolytic, hydrolytic and oxidative reactions [8]. These process being responsible for changes in the chemical and physical properties, as compared to neat oil. Most cooking oil reported in the literature used various origin of vegetable oils or WCO and in many cases the WCO oil are collected after frying a wide variety of meat, fish or vegetable products. The waste frying oil is then blended with other waste oils and being processed for further application. No study has been reported focus on the waste frying oil variation of specific cooking habit and foods.

This study aims to compare performance and emissions from diesel engine when fuelling with a conventional petroleum diesel fuel and blends of biofuels from waste cooking oil with petroleum diesel. To ensure the uniformity of the UWCO on performance and emissions, oils for UWCO were chosen from the same retrospective uses. In this experiment, UWCO blended fuel was used in diesel engine to evaluate engine performance and exhaust emissions.

II. EXPERIMENTAL SET UP AND PROCEDURES

A test rig was set up for the experimental study. It consists of a test bed, a diesel engine, a dynamometer, a fuel tank, a computer, an operation panel and a sensor to measure the exhaust temperature.

The specifications of the diesel engine are shown in Table 1. A variable speed range from 1000 to 3500 rpm with 50% throttle setting was selected for performance and emission tests. The same test procedures were followed for all the tested fuels. An EMCO gas analyzer was used to measure CO, CO_2 and NO_x emissions.

TABLE 1
ENGINE SPECIFICATIONS

Technical data	Toyota RA V4 D-4D 4 cylinder Turbocharged 1CD-FTV Diesel Engine
Bore	82.2 mm
Stroke	94.0 mm
Displacement	2.0 litres (1995 cc)
Valve mechanism	Variable valve timing, 16 valve DOHC
Maximum power	85 kW @ 4000 rpm
Maximum torque	250 Nm @ 1800 rpm – 3000 rpm
Fuel type	Diesel
Fuel injection	Common Rail Diesel Injection
Compression ratio	18.6

A conventional diesel fuel and two various proportions of UWCO/diesel blends were tested. The reference fuel is a petroleum diesel fuel similar to those available in Petronas petrol station. Samples of UWCO were collected from restaurants and from local domestic consumer. All the UWCO samples used in this study were from fryer palm oil since most local restaurants and consumer used palm oil. The UWCO utilized in the present study has no additional chemical treatments. The UWCO has been filtered to remove food residues and solid precipitate in the oil and put into containers for collection. To ensure that the oil is clean from water, the oil is heated above 100^{o}C to evaporate the moisture. The important chemical and physical properties of the UWCO were determined by standard methods and compared with diesel. The results are shown in Table 2.

A plan was designed for the experimental investigation. Two kinds of fuels (blends by volume) were tested, i.e blends of 10% UWCO and 90% diesel fuel and, 30% UWCO and 70% diesel fuel and 100% of diesel fuel (reference fuel) as shown in Table 3 and their main properties are shown in Table 4.

The tests were repeated three times for every kinds of fuel, in order to increase the reliability of the test results. During the tests, the parameters were recorded such as engine power output, fuel consumption, engine exhaust temperature and emissions. At each change of fuel, lines were drain prior to filling them with the next fuel. Before beginning the new test, the sample line was cleaned in order to make sure it is cleaned from the previous test. The engine is then warmed with the new fuel for at least 30 minutes to purge any of the remaining previously tested fuel from the engine fuel system.

TABLE 2
CHEMICAL AND PHYSICAL PROPERTIES OF DIESEL AND UWCO

Property	Diesel	UWCO
Gross HV (kJ/kg)	45609	39349
Viscosity (mPa.s)	3.743	34.700
Specific gravity	0.838	0.904
Pour point (^{o}C)	8	12
Cloud point (^{o}C)	15	21
Flash point (^{o}C)	84.8	>124.1
Carbon (%wt)	84.10	72.41
Hydrogen (%wt)	12.80	12.15
Nitrogen (%wt)	0.30	0.45
Oxygen (%wt)	2.61	14.99
Sulfur (%wt)	0.19	0

TABLE 3
TESTED FUELS

Test No.	Fuel	Fuel blended (by volume %)
1	A	Diesel
2	B	10% UWCO and 90% diesel fuel
3	C	30% UWCO and 70% diesel fuel

TABLE 4
FUEL PROPERTIES FOR THE TESTED FUELS

Property	Fuel		
	A	B	C
Gross HV (kJ/kg)	45609	44886	43630
Viscosity (mPa.s)	3.743	4.099	5.444
Specific gravity	0.838	0.844	0.860
Pour point (^{o}C)	8	9	10
Cloud point (^{o}C)	15	16	18
Flash point (^{o}C)	84.8	88.0	93.0

III. RESULT AND DISCUSSION

The engine has been operated with varying speed from 1000 – 3500 rpm and ran well on all the fuels mentioned above. The engine did not have any initial starting difficulties during operation using all the UWCO blends, although the viscosity of UWCO blended fuel was increased with increasing UWCO in the blend.

a. Effect of UWCO blends on engine performance

Fig. 1 shows the test results of the engine power output for the tested fuels at various engine speeds. The engine power increases with the increase of engine speed for all of the fuels. It was observed that all the blended fuels developed similar brake power as the reference fuel A. At higher speed fuel B and C produced lower brake power than fuel A.

This can be expected due to the slightly smaller fuel droplets and oxygen content in the fuels that contribute to slower atomization. Maximum brake power for each fuel was obtained at 3000 rpm and the value was within 37 to 46 kW. At 50% throttle position, the engine uses higher air fuel ratio, and as a result complete combustion occurs.

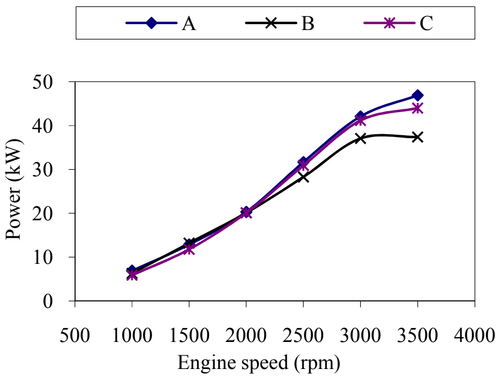


Fig. 1. Brake power output vs engine speed for the test fuels

Fig. 2 presents the test results of engine brake specific fuel consumptions (bsfc) for different fuels. The engine bsfc increases with the increasing of the engine speed. At the same time, the difference of bsfc among the blended fuels can be observed. The differences in bsfc may be a consequence of the higher density and lower calorific value of the blended fuels (B and C) compared to those of fuel A. As a result, more fuels are needed to produce the same amount of energy. Fig. 2 also shows that the minimum bsfc attained using fuel B was closer to that of A. This result indicates that the engine performance is approaching that of diesel by blending UWCO up to 10%.

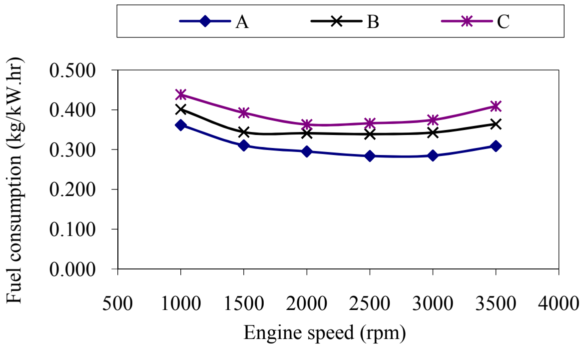


Fig. 2. Fuel consumption vs engine speed for the test fuels

Fig. 3 compares the brake thermal efficiency for the tested fuels. It is evident that the thermal efficiency of the blended fuel (B and C) was lower than fuel A at all engine speed. The possible reasons for the reduction in thermal efficiency may be the lower heat content, higher density, higher viscosity and poor volatility of the fuels compared to fuel A. These properties, which are significantly different with those of fuel A, would have resulted in lower thermal efficiency and higher exhaust gas temperature. Among the blended fuels, fuel B shows a closer thermal efficiency to fuel A.

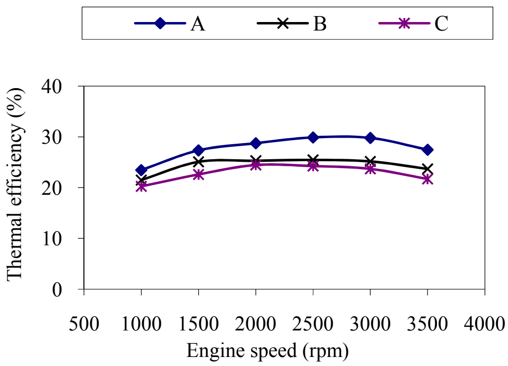


Fig. 3. Thermal efficiency vs engine speed for the test fuels

Fig. 4 shows the variations of exhaust gas temperature with respect to the engine speed for the engine using the tested fuels. The exhaust temperatures increase with the increase of engine speed for all of the fuels. It also indicates the effect of blending proportion on exhaust gas temperature. It can be seen that the exhaust gas temperature was increased with the increase of UWCO content in the blends. This may be due to the increase in the combustion gas temperature. The exhaust gas was higher for the fuels B and C fuel than fuel A as the blended fuels contains constituents of poor volatility, which burn only during the late combustion phase [1].

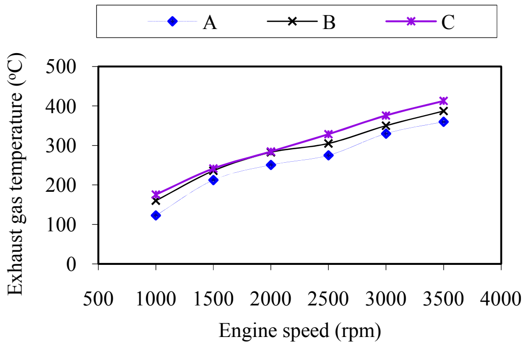


Fig. 4. Exhaust gas temperature vs engine speed for the test fuels

b. Effect of WCO blends on exhaust emissions

Fig. 5 shows the CO emission for the tested fuel for various engine speeds. Within the experiment range, the CO emissions from the blended fuels (B and C) are nearly all higher than that of fuel A. This may due to the high viscosity of the UWCO, which causes poor spray characteristics, forming locally rich air-fuel mixtures during the combustion process leading to CO formation during the combustion, due to the lack of oxygen locally.

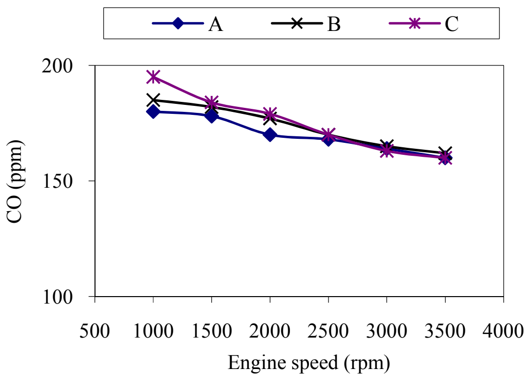


Fig. 5 CO emission vs engine speed for the test fuels

Fig. 6 shows the CO_2 emissions of different fuels from the engine at different engine speeds. It shows that the CO_2 emission of fuel A is higher than that of other fuels. This is because UWCO contains oxygen element, the carbon content is relatively lower in the same volume of fuel consumed at the same engine speed, and consequently the CO_2 emissions from the blended fuels are lower.

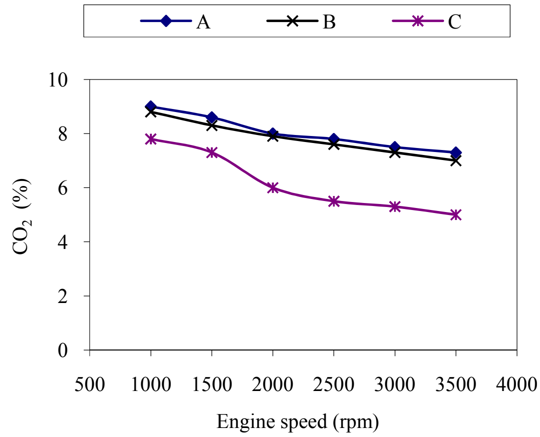


Fig. 6 CO_2 emission vs engine speed for the test fuels

Fig. 7 shows the NO_x emission for the tested fuels at various engine speeds. It can be seen that the NO_x emission varies with the engine speed. This trend was occurred as NO_x formation is a temperature dependent phenomenon. As the engine speed increases, the combustion gas temperature increases, which in turn increases the formation of NO_x. Among the blended fuels, Fig. 7 also indicates that the NO_x emission was lowered with the substitution of fuel B as fuel. This positive trend may be because of the lower peak combustion temperature due to the lower heat content of UWCO.

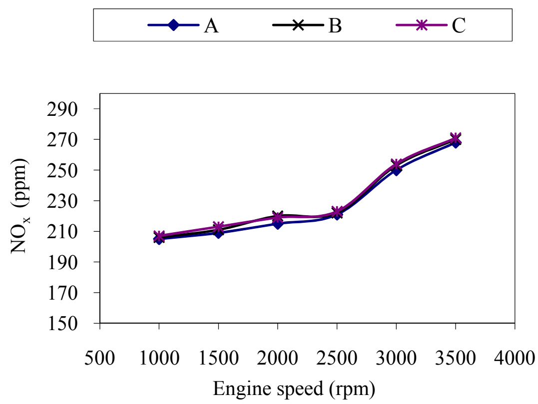


Fig. 7 NO_x emission vs engine speed for the test fuels

IV. CONCLUSION

The experimental results show that the use of UWCO/diesel blend is possible. Blending of UWCO with diesel seems to be an effective technique to decrease the viscosity of the UWCO. Reasonable viscosity values have been obtained using blending ratios as high as 30%UWCO and 70% diesel. Other fuel properties such as heating value, specific gravity and flash point are comparable. The blends containing 10% and 30% of UWCO yielded the properties closely matching that of diesel.

The experimental results also show that the engine fuelled by UWCO blends performed well and are comparable with the performance run by the diesel fuel. The engine power output and the fuel consumption of the engine are almost the same when the engine is fuelled with UWCO blends compared with that of diesel.

The emissions of CO from UWCO blends are slightly higher while the emissions of CO_2 and NO_x are lower and closer to that of diesel fuel. This emission character found in the tests is of significance to some extent for replacing diesel fuel with the UWCO blends in the future.

UWCO/diesel blends possessing good fuel properties and provides good engine performance. Since they are from palm oil, they are environment friendly, biodegradable and renewable. UWCO may be preferred choice in terms of cost, since it is essentially a waste product and it is cheaper than unused oils.

The above observations indicate a good potential of using UWCO/diesel blends as an alternative compression ignition engine fuel and encourage continuation of the present experiment program

ACKNOWLEDGEMENT

The authors would like to thank Department of Mechanical and Material Engineering and Department of Chemical and Process Engineering, National University of Malaysia for kindly providing the facilities and extending necessary help to conduct the study.

REFERENCES

[1] M. Lapuerta, J.R Fernandez and J.R. Agudelo, “Diesel Particulate Emissions from used cooking oil biodiesel”. *Bioresourse Technology*. Article in Preess. Jan. 2007.

[2] M. Pugazhvadivu and K. Jeyachandran, “Investigations on the performance and exhaust emissions of a diesel engine using preheated waste frying oil as fuel,” *Renewable Energy*, vol. 30, pp. 2189-2200, March 2005.

[3] Y.M. Choo, C.L. Yung, S.F. Cheng, A.N. Ma, A.N., C.H Chuah, and Y. Basiron, “Key fuel properties of palm oil alkyl esters,” *Fuel,* vol. 84, pp. 1717-1720, March 2005.

[4] C.D Rakopoulos, K.A. Antonopoulos, D.C. Rakopoulos, D.T Hountalas, and E.G. Giakoumis, “Comparative performance and emissions study of a direct injection Diesel engine using blends of Diesel fuel with vegetable oils or bio-diesels of various origin,” *Energy Conversion and Management*, vol. 47, pp. 3272-3287, March 2006.

[5] M. Al-Widyan, and A.O. Al-Shyoukh, “Experimental evaluation of the transesterification of waste palm oil into biodiesel,” *Bioresource Technology*, vol. 85, pp. 253-256, May 2002.

[6] T. Ghassan, M. Al-Widyan, and A.O. Al-Shyoukh, “Combustion performance and emissions of ethyl ester of a waste vegetable oil in a water-cooled furnace,” Applied *Thermal Engineering*, vol. 23, pp. 285-293, Oct. 2003.

[7] D.Y.C. Leung, and Y. Guo, “Transesterification of neat and used frying oil : Optimization for biodiesel production,” *Fuel Processing Technology*, vol. 87, pp. 883-890, June 2006.

[8] G.K. Mangesh, and K.D. Ajay, “Waste Cooking Oil – An Economical Source for Biodiesel : A Review,” *Ind. Eng. Chem. Res.,* vol. 45, pp. 2901-2913, March 2006.