PREPARATION AND CHARACTERIZATION OF UNTREATED WASTE PALM OIL/DIESEL FUEL BLEND

M. I. Ali, S. Abdullah,T. I Mohamad, W. R. W. Daud

Faculty of Engineering and Built Environment,
Universiti Kebangsaan Malaysia,
43600 Bangi, Selangor, Malaysia

Email: misra63@yahoo.com

ABSTRACT

Some diesel engines can run on some kinds of vegetable oil under some conditions without problems. To use vegetable oils in diesel engine without modification, it is necessary to make sure that the vegetable oils properties must be similar to diesel fuel. In this study, palm oil that has been used several times for frying purposes is investigated for the utilization as an alternative fuel for diesel engines. The waste palm oil has a variety of qualities, possess properties different from that of neat oils. Higher impurities of the used oils make them different from neat vegetable oil. The high viscosity of the waste palm oil was decreased by blending with diesel. Two different previous uses of waste palm oil were blend with diesel. The blends of varying proportions of waste palm oil and diesel were prepared, analyzed and compared with diesel fuel and the waste palm oil ethyl ester. The properties of the blends such as heating value, viscosity, specific gravity, etc. were determined. It was found that blending waste palm oil with diesel reduces the viscosity and different previous uses of waste palm oil significantly affected the properties of the blended fuels. From the properties test results it has been established that blends containing 5 to 40% of waste palm oil in diesel yielded the properties closely matching that of diesel.

KEYWORDS*: alternative fuel; waste frying oil; renewable energy.*

1.0 INTRODUCTION

The increasing production of waste frying oils from household and industrial sources is a growing problem all around the world. The United States produces about 3 billion gallons (roughly 11 billion liters) per year of waste frying oil (Pugazhvadivu, 2005). In Malaysia, the average domestic consumption for cooking oil is 40,000 to 50,000 tonnes per month and even exceeded the normal monthly demand to reach over 70,000 tonnes, especially during festive seasons. If 5%

of these could be considered as waste frying oil, it might cause big problem to dispose the waste frying oil.

Nowadays, most of the waste frying oil is poured into the sewer system. This practice contributes to the pollution of rivers, lakes, seas and underground water, which is very harmful for environment and human health. In this situation, the waste frying oil must either be disposed of or recycled in some way. From the viewpoint of sustainability, the used of waste frying oil as fuel offers a plausible means by which it can be recycled. Waste frying oil is produced after repeated frying of a variety of foods in vegetable oils and it offers a significant potential as an alternative low-cost fuel.

Many researchers have shown that vegetable oils (neat or used) can be used as diesel substitutes. Several vegetable oils have been evaluated including soybean oil, sunflower oil, cotton-seed oil, peanut, coconut, palm, etc. (Ramadhas, *et.al.*, 2004; Altin, *et.al.*, 2001; Kalam, *et.al.*, 2003; Rakopoulus *et.al.*, 2006). Most of the researchers found that vegetable oils pose some problems when subjected to prolonged usage in compression ignition engines because of their high viscosity. The common problems are poor atomization, carbon deposits, ring sticking, fuel pump failure, etc. (Choo *et.al.*, 2005). The literature also shows that a large amount works have done into evaluating the conversion the waste frying oil to biodiesel. 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. 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.

Waste frying oil used in industrial or household frying undergo degradation by thermolytic, hydrolytic and oxidative reactions (Mangesh, 2006). These process being responsible for changes in the chemical and physical properties, as compared to neat oil. Most frying oil reported in the literature used various origin of vegetable oils or waste frying oil and in many cases the waste frying 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.

To use waste frying oil in diesel engine without any modification, it is necessary to make sure that the waste frying oil properties must be similar to diesel fuel. In this study, waste frying oil with different previous uses was blend with diesel and compares their respective fuel properties with waste palm oil ethyl ester and Malaysian Petroleum Diesel. The main objective of this study were to decrease the viscosity of waste frying oil by blending with diesel, to examine the influence of different types of food on reduction in viscosities of the blend and other important properties of the fuel. Future work will involve test on engine performance and emissions.

2.0 EXPERIMENTAL PROCEDURE

Samples of waste frying oil (WFO) were collected from restaurants and from local domestic consumer. All the WFO samples used in this study were from fryer palm oil since most local restaurants and consumer used palm oil. The fatty acid composition of palm oil is dominated by palmitic, oleic, linoleic, and stearic fatty acids plus much less proportions of myristic, lauric, linolenic, and capric acids (Al-Widyan *et.al.*, 2002). Two types of WFO were used in the experiments. The first one was mainly used for frying flour-based food and referred as WFOA. The second one was mainly used for frying chicken or fish and referred as WFOB. The WFO utilized in the present study has no additional chemical treatments. The WFO has been filtered to remove food residues and solid precipitate in the oil. To ensure that the oil is clean from water the oil is heated above 100^{o}C to evaporate the moisture.

Blend of WFO with diesel have been prepared in the laboratory for experiment measurements. Different blend ratios have been selected for measurements and evaluation. The blend ratios include 5, 10, 15, 20, 30, 40, 50, 60 and 70 percent by volume of WFO in a mixture of WFO in diesel. They are referred to as diesel, for example 5WFOA-95D means 5% WFOA and 95% diesel. The reference fuel is a petroleum diesel fuel similar to those available in Petronas petrol station. The pure diesel fuel was tested to establish the 0% blending point and pure WFO were tested to establish the 100% WFO points.

Several tests were conducted to characterize the blended fuel, diesel and the pure WFO according to ASTM Standard methods. This is to compare various physical, chemical and thermal properties of the fuels. Various procedures followed and the instruments used are given in Table 1.

TABLE 1
ASTM Methods and Instrument to Measure Various Properties

Property	ASTM Method	Instrument
Gross heating value	ASTM D240	IKA Werke Bomb Calorimeter
Viscosity	ASTM D445	Haake Viscometer
Specific gravity	ASTM D1298	Hydrometer
Pour point	ASTM D97	Pour point Apparatus
Cloud point	ASTM D2500	Cloud point Apparatus
Flash point	ASTM D93	Setaflash Tester
Carbon (%wt)	-	Elemental Analyzer
Hydrogen (%wt)	-	Elemental Analyzer
Nitrogen (%wt)	-	Elemental Analyzer
Oxygen (%wt)	-	Elemental Analyzer
Sulfur (%wt)	-	Elemental Analyzer

3.0 RESULT AND DISCUSSION

The important chemical and physical properties of the pure WFO were determined by standard methods and compared with diesel and its ethyl ester. The analytical results are shown in Table 2. The ester of WFO was found in the literature (Al-Widyan, 2002).

The results show that the gross heating value of the WFOA and WFOB are comparable to the diesel fuel and its ethyl ester. The measured heating value of both WFO is approximately 13.5% lower than diesel and 0.09% higher than its ethyl ester.

As expected, the viscosity of both WFOA and WFOB are significantly higher than those of other types of fuel. The viscosity of the diesel fuel is 3.743 mPa.s at 40oC while the viscosity of both WFO is 9.2-9.8 times that of diesel fuel. Blending with other fuel might reduce the viscosity and therefore eliminates this problem.

The specific gravity of both WFOA and WFOB were also found higher than that of the diesel fuel and varied from 0.904-0.905, while the specific gravity of the ester was significantly lower than that of both WFO. In comparison, the WFO had an average of 7.3% higher specific gravity than that of diesel fuel. Both WFO contained approximately 13.5% less heat energy on a mass basis. Since the specific gravity of the WFO was 7.3% higher than diesel fuel, the heat energy of the WFO therefore was about 6.2% lower on a volume basis.

The pour point and cloud point of both WFO were found higher than diesel by 4°C and 6°C, respectively. Higher pour point and cloud point reflect unsuitability of WFO as diesel fuel in cold climate conditions. The flash points of both WFO were also found quite high compared to diesel. Hence the WFO is extremely safe to handle.

Carbon, hydrogen, nitrogen, sulfur and oxygen (CHNSO) content were also measured for diesel and WFO. It has been observed that the value of carbon and hydrogen content of pure WFO are much lower compared to the values of diesel. Thus the carbon/hydrogen ratio, which depends upon the degree of unsaturated of WFO, is different from diesel. Presence of nitrogen in the fuel might contribute NO_x emissions and presence of oxygen in the fuel will improves the combustion properties and emissions but reduces the heating value of the fuels. The sulfur contents for the WFO are very low and could not be detected and it is assumed zero. Low sulfur content of both WFO will results in lower SO_x emissions.

TABLE 2
Physical and Chemical Properties of Fuels

Property	Diesel	WFOA	WFOB	Ethyl ester
Gross HV (kJ/kg)	45609	39340	39349	39305
Viscosity (mPa.s)	3.743	36.700	34.700	13.05
Specific gravity	0.838	0.905	0.904	0.874
Pour point (°C)	8	12	12	0
Cloud point (°C)	15	21	21	0
Flash point (°C))	84.8	>124.0	>124.1	109
Carbon (%wt)	84.10	72.96	72.41	NA
Hydrogen (%wt)	12.80	11.82	12.15	NA
Nitrogen (%wt)	0.30	0.49	0.45	NA
Oxygen (%wt)	2.61	14.73	14.99	NA
Sulfur (%wt)	0.19	0	0	NA

NA indicates not available

Tests were also conducted using blends of WFO with petroleum diesel. Figure 1 shows the gross heating value (GHV) of various blends of the WFO. GHV of WFO is lower compared to that of diesel, therefore it was observed that the GHV of the blends were decreased with the increasing percentage of WFO in the blends. The blends maintained a similar trend for both WFO, but the GHV were slightly higher for WFOB compared to WFOA.

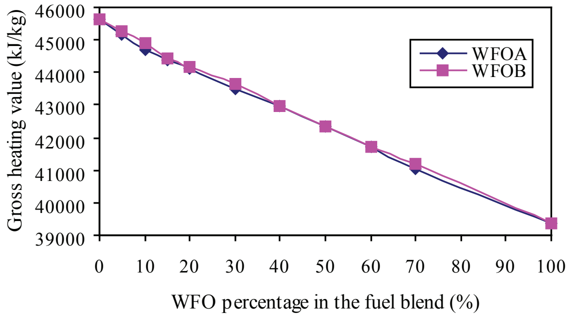

FIGURE 1 Effect of blends on Gross Heating Value

In general, the GHV of the blends are lower than that of diesel. The GHV is expected to affect the fuel consumptions of the engine.

Higher viscosity is a major problem in using waste frying oil as fuel in compression ignition engines. The viscosity of various blends of WFO and diesel were evaluated at 40^{o}C. It shows that when WFO mixed with diesel to make blends, it is found that the more percentage of WFO in the blends, the higher of the viscosity. This happens to both of WFO, but WFOB gives better reduction in viscosity compared to WFOA at any percentage of blends. For example, a reduction of 87.3% and 88.4% for WFOA and WFOB was achieved with 5WFOA-95D and 5WFOB-95D, respectively.

The injection system of a diesel engine is designed to operate with diesel fuels, which has a viscosity of 3 – 8 mPa.s (Bari *et.al,* 2002) and the ASTM limit for viscosity of diesel fuel is 5 cst. (Deepak, 2007). It can be seen that, the viscosity of both WFO up to 40% blend ratio can be used as diesel substitute as the viscosity are within the design limit. It is always desirable for the WFO to have a viscosity value nearer to that of diesel. This is because the higher the viscosity, the more difficult it is to atomize for the WFO and its blends. Blending of WFO with diesel seem to be an effective tool to overcome engine problems associated with the high viscosity of WFO.

The variation of the specific gravity with various WFO/diesel blends were also evaluated and is shown in Figure 3. It has been observed that up to 40% WFO/diesel blends for both WFO produce slightly higher than diesel. This however, is not important, as this would only cause a slight increase of fuel consumption. The specific gravity of WFOA is found higher than WFOB at all level of blends. More dense fuel will provide greater energy per gallon of fuel.

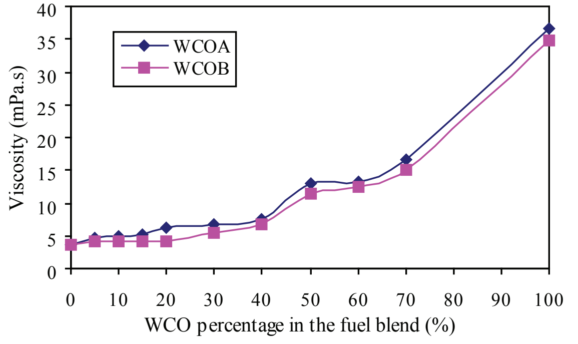

FIGURE 2 Effect of blending on viscosity

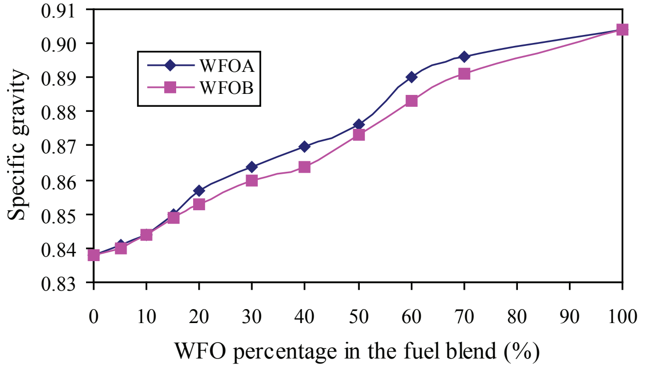

FIGURE 3 Effect of blending on specific gravity

Effect of blending on pour point is shown in Figure 4. Pour point is defined as the lower temperature that the fuel can be poured by gravity. As the WFO concentration in the blend was increased, the pour point was increased. WFOB provide slightly lower cold flow properties than WFOA.

The WFO/diesel blends were also evaluated for their cloud points. Cloud point is the temperature of which a cloud of wax crystal first appears in the fuel when it is cooled. The effect of blending on cloud point is shown in Figure 5. Both WFO exhibits cloud points ranging from 15 to 19°C for the blending ratio from 5 to 60% of WFO. The differences of cloud point between WFOA and WFOB are very small at all percentage in the fuel blend.

A key property determining the flammability of a fuel is the flash point. It is a measure of the tendency of a sample to form a flammable mixture with air. The flash point temperature is critical from a safety viewpoint. The flash point must be as high as practical. Blending of WFO with diesel reduces the value of the flash point of the blend. However, the flash point of the different blend ratio for both WFO is relatively higher than that of diesel. As can be observed in Figure 6, WFOA exhibit greater flash points than WFOB at all blends.

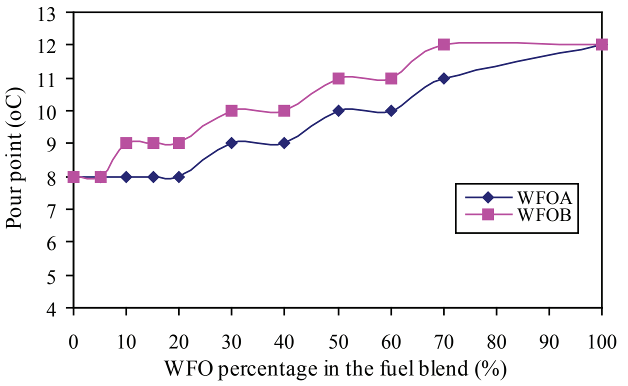

FIGURE 4 Effect of blending on pour point

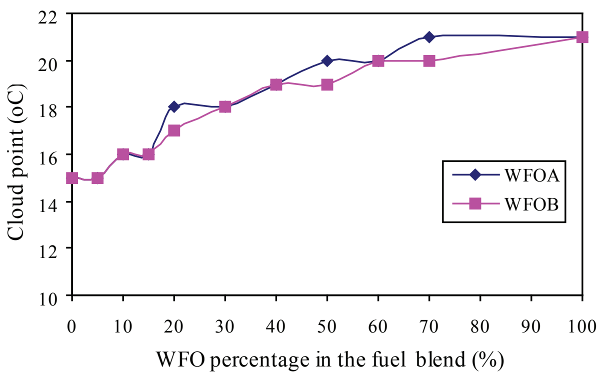

FIGURE 5 Effect of blending on cloud point

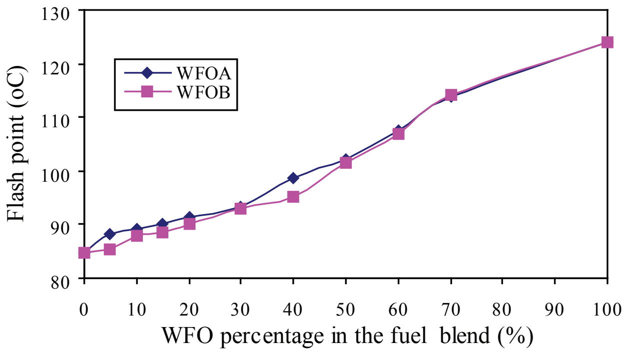

FIGURE 6 Effect of blending on flash point

Blending of WFO with diesel is also found reduces the value of carbon and hydrogen content in the blends (Figure 7 and Figure 8). This is expected to the reduction in CO_2 emissions for the blended fuels because of the lower amount of carbon content in the fuel as shown in fuel properties of WFO/diesel blends.

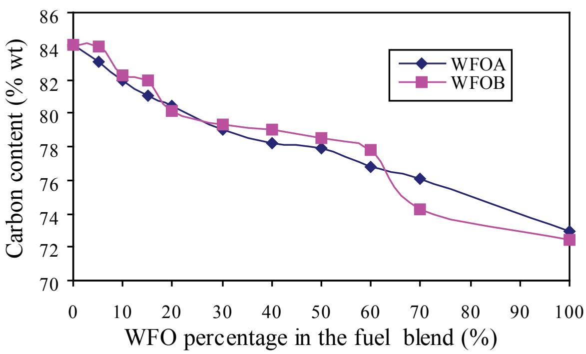

FIGURE 7 Effect of blending on carbon content

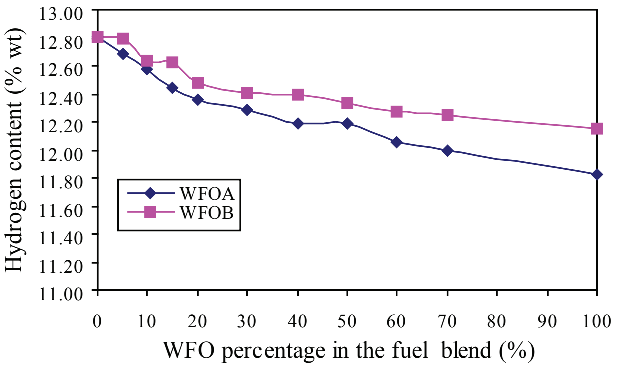

FIGURE 8 Effect of blending on hydrogen content

4.0 CONCLUSION

The experimental results show that the use of WFO/diesel blend is possible. Blending of WFO with diesel seems to be an effective technique to decrease the viscosity of the WFO. Reasonable viscosity values have been obtained using blending ratios as high as 40%WFO and 60% diesel. Other fuel properties such as heating value, specific gravity and flash point are comparable. The blends containing 5-40% of WFO yielded the properties closely matching that of diesel.

Different previous uses of WFO influence the properties of the fuel blends. This may due to changes of the molecular structure of the WFO as well as the nutrients, aromatics or other compounds that may have been introduced during frying. In general, WFOB gives better properties and comparable to that of diesel.

WFO/diesel blend possessing good fuel properties. Since they are from palm oil, they are environment friendly, biodegradable and renewable. WFO 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 WFO/ diesel blends as an alternative compression ignition engine fuel and encourage continuation of the present experiment program.

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6.0 REFERENCES

Pugazhvadivu. M., Jeyachandran, K. 2005. Investigations on the performance and exhaust emissions of a diesel engine using preheated waste frying oil as fuel. Renewable Energy. 30: 2189-2200.

Ramadhas, A.S., Jayaraj, S., Muraleedharan, C. 2004. Use of vegetables oil as I.C engine fuels – A Review. Renewable Energy. 29: 727-742.

Altin, R., Cetinkaya, S., Yucesu, H.S. 2001. The potential of using vegetables oil fuels for diesel engines. Energy Conversion and Management. 42: 529-538.

Kalam, M.A., Husnawan, M., Masjuki, H.H. 2003. Exhaust emission and combustion evaluation of coconut oil-powered indirect injection diesel engine. Renewable Energy. 28: 2405-2415.

Rakopoulos, C.D., Antonopoulos, K.A., Rakopoulos, D.C., Hountalas, D.T., Giakoumis, E.G. 2006. 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. 47: 3272-3287.

Choo, Y.M., Yung, C.L., Cheng, S.F., Ma, A.N., Chuah, C.H., Basiron, Y. 2005. Key fuel properties of palm oil alkyl esters. Fuel. 84: 1717-1720.

Mangesh, G. K., Ajay, K. D. 2006. Waste Cooking Oil – An Economical Source for Biodiesel : A Review. Ind. Eng. Chem. Res. 45: 2901-2913

Praminik, K. 2003. Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine. Renewable Energy. 28: 239-248.

Al-Widyan, M., Tashtoush, G., Abu-Qudais, M. 2002. Utilization of ethyl ester of waste vegetable oils as fuels in diesel engines. Fuel Processing Technology. 76: 91-103. .

Al-Widyan, M., Al-Shyoukh, A.O. 2002. Experimental evaluation of the transesterification of waste palm oil into biodiesel. Bioresource Technology. 85: 253-256.

Bari, S., Lim, T.H., Yu, C.W. 2002. Effects of preheating of crude palm oil (CPO) on injection system, performance and emission of a diesel engine. Renewable Energy. 27: 339-351.

Deepak, A., Avinash Kumar, A. 2007. Performance and emissions characteristics of Jatropha oil (preheated and blends) in a direct injection compression ignition engine. Applied Thermal Engineering. Article in Press.