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Transesterification of Biodiesel: Process Optimization and Combustion Performance

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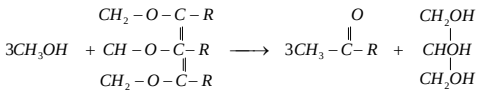
Abstract

Biodiesel is a renewable fuel produced by a chemical reaction of alcohol and vegetable or animal oils, fats, or greases leaving behind Glycerol. Biodiesel offers a safer and cleaner alternative to petroleum Diesel. It is a promising solution to the ever increasing demand of diesel, providing a technology for production of fuel of beyond properties to that of conventional petrodiesel. In this work several transesterification experiments were carried out in attempt to find the best yield parameters including amount of catalyst and methanol, temperature, and processing time. A well-controlled dissolution apparatus is used to carry out several iso-conditions experiments simultaneously but at different residence time. Properties of the biodiesel were assessed following American Society of Testing and Materials (ASTM) testing procedures (density, flash point, vapor pressure, viscosity, boiling point, melting point, and distillation T90) followed with evaluation to the Fatty Acid Methyl Ester (FAME) purity utilizing Flame Ionization Detector – Gas Chromatography Mass Spectroscopy (FID-GCMS). Results show that the produced biodiesel fall within the standard range and with a best yield of 93% at 12:1 alcohol to oil ratio, at temperature of 60oC, and reactor agitation speed of 400 rpm (400 rpm or 500 rpm – see table 2). Biodiesel fuel blends B05, B10, B15 and B20 were prepared and tested in a small 8 horse power Robin Diesel Engine. The torque and the break engine horsepower were obtained using engine dynamometer. Real time monitoring of engine emissions was performed using gas analyzer. The measurements include O2, CO, CO2, HC's, and NOX. The results show a net decrease of HC and CO emissions for the Biodiesel fuel blend compared to Diesel Fuel while the change of engine power and NOx emissions were negligible.

Keywords: Biodiesel; *Renewable-Energy, Transesterification, Waste –oil, Chemical-Kinetics.*

1. Introduction

The reliance on Internal Combustion (IC) engines (for marine, transport, agriculture, etc.) has made countries and communities more dependent on the local and global availability of diesel fuel. Biodiesel can offset significant portion of this fuel in areas not known as oil producing countries. It is a mono-alkyl esters of vegetable oils, animal fats, and used cooking oil. Vegetable oils are primarily composed of triacylglycerols – a form of lipids comprised of 3 fatty acid molecules attached to a glycerol backbone, and to a lesser extent diacylglycerols and monoacylglycerol. Transesterification is the process wherein vegetable oil or fats react with alcohol, in the presence of a catalyst to form alkyl esters and glycerol [1]. The reaction happens through three consecutive and reversible reactions. In the first step diglyceride is produced from triglycerides, in the second step monoglyceride is produced from diglyceride, and in the last step glycerin is produced from the monoglycerides. A Fatty Acid Methyl Ester (biodiesel) molecule is produced in each step as depicted in the overall equation below.



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Due to immiscibility of the oil-alcohol and reversibility of the reaction, a catalyst (sodium hydroxide NaOH or potassium hydroxide KOH) and higher alcohol molar ratio is often applied to maximize ester production [1]. Reaction times for typical biodiesel production range from 30 minutes to more than 2 hours and with catalyst concentrations of 0.1 to 2% [2, 3]. Variation is due to degree of unsaturation in the fatty acid molecules [4] and the contents of Free Fatty Acids (FFA). Excessive FFA contents lead to formation of soap instead.
Biodiesel is an alternative fuel that can be used to reduce global warming gas emissions such as carbon dioxide CO2, tailpipe particulate matter (PM), total hydrocarbon (HC), and carbon monoxide CO from most modern IC engines. These advantages made car manufactures to warranty the utilization of biodiesel in their engine up to 20 % blends (B20) under minor engine modifications [5]. Biodiesel fuel is commonly produced from soybean oil in America, rapeseed in Europe, palm oil in tropical regions. It is also produced from Jatropha, corn oil, canola oil, cottonseed oil, mustard oil, restaurant waste oils such as frying oils, animal fats such as beef tallow or lard, trap grease (from restaurant grease traps), float grease from waste water treatment plants [6]. Table 1 summarizes the oil feed stocks used for biodiesel production.

Table 1: Biodiesel oil feed stocks

Non-edible	Edible	Waste
Jatropha	Soybean	Waste cooking
Rapeseed	Palm tree	Tallow
Castor	Rapeseed	Soap stock
Pongamia pinnata	Canola oil	Trap grease
Sea mango and algae	Sunflower	Waste cooking
Seashore mallow	Methanol	

The oil or animal fat can be converted to Fatty Acid Methyl Ester or Ethyl Esters (biodiesel) directly, using alcohol (methanol or ethanol) and base catalyze to accelerate the reaction. The most common method of production of biodiesel is by mixing the vegetable oil with methanol in the presence of sodium hydroxide NaOH [7]. The reaction produces Fatty Acid Methyl Esters (Biodiesel) and Glycerin (by product).

Add some previous studies from the literature (numerical and experimental studies) about Biodiesel production and combustion and emission chracaterization.

In this study, waste cooking oil is collected from different restaurants to produce biodiesel. It is subjected to several transesterification conditions with the objective of producing biodiesel at comparable or better thermochemical properties as to the standard petroleum diesel. The use of pure Biodiesel (B100) in internal combustion engines requires some engine modification to prevent any decomposition of plastic (tubing and seals) parts. More commonly biodiesel runs as a blend of B5, B10, and B20 (Example: B20 is 20% of biodiesel blended with 80% of petroleum diesel) [8]. The performance and emissions testing of diesel engine using different biodiesel fuel blends (B5, B10, B15 and B20) was also performed in this study.

2. Material and Methods

Waste frying oil (mixture of sunflower oil and palm oil) was collected from a local restaurant. The waste frying oil was filtered through a 12μm filter and water was removed by heating the oil to 70°C for 1 hour.

2.1. Titration and pretreatment

Titration was performed in order to determine the amount/fraction of Fatty Fat Acid (FFA) present in the oil samples. A 0.1% concentration sodium hydroxide water solution was titrated into a mixture of 1 ml vegetable oil, 10 ml of isopropyl alcohol, and 5 drops of phenolphthalein pH indicator. The added amount of solution indicates the acidity of the oil as the reaction goes to completion when all the FFA is neutralized, showing a color change of the phenolphthalein indicator. The acid value expressed as:

$$Acidvalue = \frac{Vol_{NaOH} x Conc_{NaOH} x MW_{KOH}}{Sampleweight(g)} \quad (2)$$

2.2. Transesterification experiments

Transesterification experiments were performed in the modified VK 7010 Dissolution Apparatus of 8 bioreactors shown below in figure1. Each reactor has a capacity of a 1.0 liter, separate stirring, whereas they all submerged in temperature control water-bath.

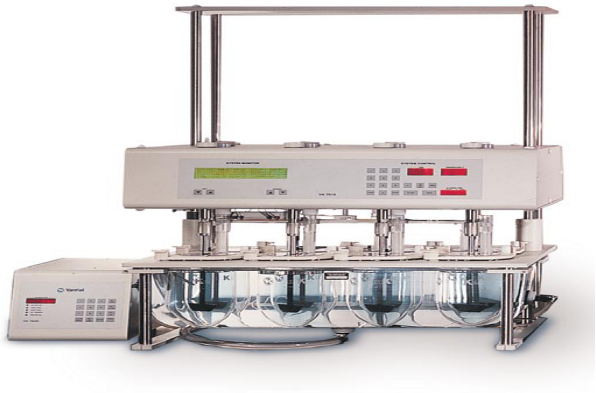

Figure 1: Varian VK 7010 Dissolution Apparatus that modified as multiple bioreactor.

2.3. Biodiesel Production method

The biodiesel fuel was produced through the NaOH as base catalyst transterification and the process diagram is presented in figure 2. This provides one of the easiest and more efficient ways to produce the fuel, yielding a return of close to 98%. The waste cooking oil is first heated up to 70°C to evaporate any water present and filtered to eliminate any solid particles in the oil. After that, a titration was performed to determine the exact amount of base catalyst needed for the reaction based on the amount of biodiesel fuel to be produced. Homogeneous transesterification was performed using the NaOH as a catalyst (KOH was also tested but nor the yield percentage or quality were in close match to NaOH catalyst) and the oil to alcohol were examined at 12:1 and 6:1 molar ratios. Note – it is oil to alcohol or alcohol to oil (see abstract). Reaction temperature was set at 60°C in one experimental set and at 70°C in other set following previous experimental guidelines [9].

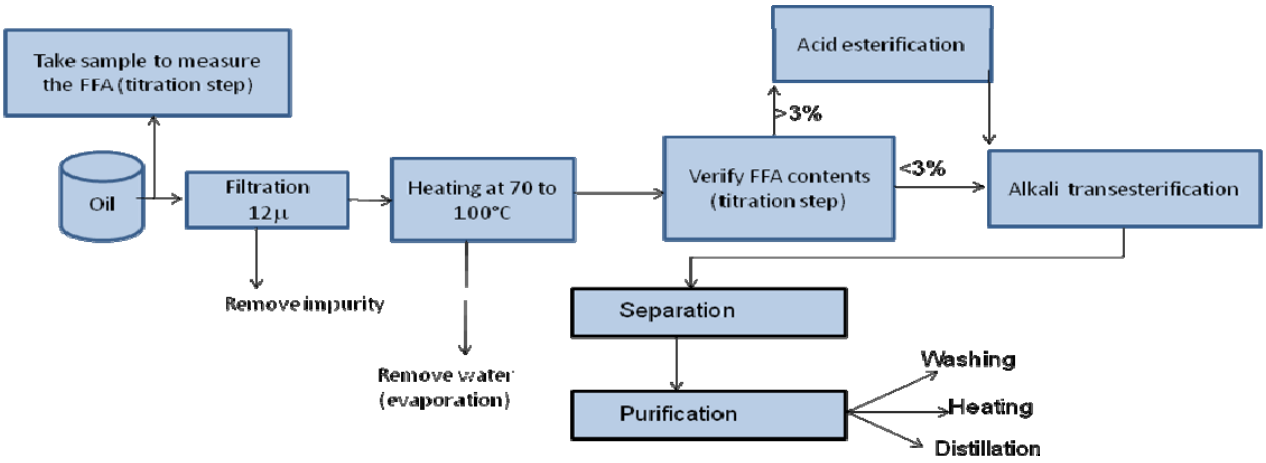

Figure 2: Transesterification following a base catalyst process

The specified alcohol amount (methanol or ethanol) was mixed with the solid catalyst and kept on a magnetic stirrer until the catalyst was totally dissolved and heated to reaction temperature. The sodium methoxide was added to these bioreactors and reaction time is triggered when the oil/methoxide mixture is reached the specified reaction temperature. Table 2 shows the conditions for the different transesterification experiments.

Table 2. Reaction conditions used in transesterification of waste frying oil (WFO) at T=60ºC and 400 rpm

Exp.	Alcohol	Molar alcohol: oil	Catalyst	Catalyst conc. (%)	Time (min)
1	Methanol	12:1	NaOH	1	2
2	Methanol	12:1	NaOH	0.75	2
3	Methanol	12:1	NaOH	0.5	2
4	Methanol	6:1	NaOH	1	2
5	Methanol	12:1	NaOH	1	1
6	Methanol	6:1	NaOH	1	1

Excess amount of FFA typically lead to soap formation with the base catalyst following the side reaction below.

$$FFA + Alcohol \overset{catalyst}{\leftrightarrow} FAME + H_2O$$
$$FFA + KOH \leftrightarrow Soap + H_2O \quad (3)$$
$$Triglyceride + 3H2O \leftrightarrow 3FFA + Glycerol$$

Note – the catalysts is NaOH or KOH

Separation and purification take place following the transesterifiation and as the mixture is left to settle down for 7 to 8 hours (see Figure 3: the biodiesel is on the top and glycerin is in the bottom). After the separation of Glycerin from the Biodiesel, the fuel is washed with water and dried to remove any excess methanol and glycerin present in the final product (B100 Biodiesel fuel). Some B100 fuel samples are used for ASTM property assessment (see table 3) and other samples are used in the GC-MS that equipped with split less FID FAME column to assess the biodiesel purity properties. Figure 3 shows a sample of the final product or B100 biodiesel fuel.

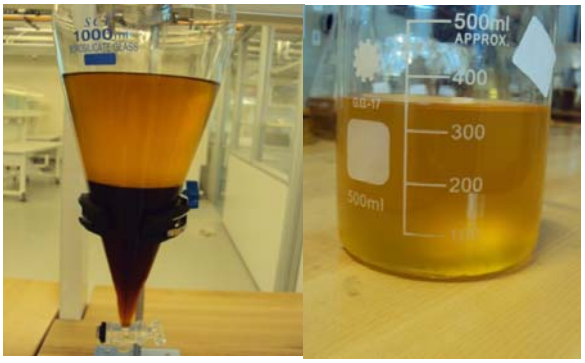

Figure 3: Biodiesel processor, Biodiesel/Glycerin mixture, and pure biodiesel fuel

LOIP LP-092S open-cup flash point analyzer was used to measure the flash point of the produced biodiesel. This flash-point analyzer is operated according to GOST 4333-87 and ISO 2592 in a temperature range from +79 to +400 °C. The analyzer incorporates control devices to adjust the heating rate of a sample. The operation conditions are with the start temperature of 20 °C, the test interval of 2°C and the heat rate during the experiment equal to 5.5 °C/min. The flash point is tested with the igniter at specified temperature intervals. The flash point of each sample was measured under atmospheric pressure. Other testes were run using the standard summarized in table 3 below:

Table 3: Experimental tests and laboratory apparatus employed

Experimental	Apparatus
Distillation ASTM D-110/IP-24	Vacuum distillation
Initial boiling point	Gecil process
Density ASTM D-1298	Hydrometer
Water content ASTM D-1796	Distillation
Sediment ASTM D-1796	Centrifuge
Flash point ISO 2592	Cleveland open/close cup
Total sulfur ASTM D-4294	MiniPal
Kinematic viscosity ASTM D-2170	Viscometers
Pour point ASTM D-2170	Viscometers
Salt content IP-77	Separation flask
Heating value ASTM D-240	Parr 600 Bomb Calorimeter
Heavy metals, Fe, Na, K, V,& Ni, Ca, Mg, Si	ICP

2.4. Diesel Engine testing

The Diesel engine used for this study is an air cooled, 4-cycles, single cylinder and 8 horse power Robin Engine. A Dynomite water cooled dynamometer was used to measure the torque and the number of rotation per minute and determine the engine horse power. The Diesel engine is compact, lightweight and designed for generators, pumps and compressors. Figure 4 shows the unit mounted on the dynamometer. The engine has a fuel tank of a capacity of approximately 14.5 liters (3.83 gallons), and a maximum horsepower rating of 8 HP with a displacement of 348 cubic centimeters.

Figure 4: Eight Horse power Diesel Engine and Dynamometer assembly

The engine performance is accessed via dynamometer with water brake load system. The pump pressurizes the water which then goes into the water brake connected to the engine shaft. Part of the energy produced by the engine goes to the exhaust while the rest of it is released as calorific calories to the water that passes thru the water brake. For this reason the water has to be cooled down, as it will over heat over time and loose efficiency. The dynamometer is equipped with sensors, data acquisition system and software (See Figure 5) to measure the Torque and RPM. The measured values of the torque and RPM are used to determine the horsepower:

$$\text{Horsepower} = (\text{RPM} * \text{Torque}) / 5252 \qquad (3)$$

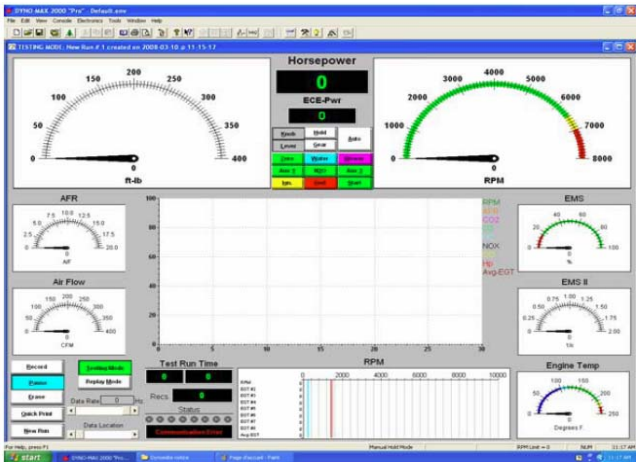

Figure 5: Data acquisition interface for engine testing

Engine Exhaust Gas Measurements

A gas analyzer DYNOmite EMS (See Figure 6) was used in this study to measure the emissions from the engine. The real time gas analyzer is used to measure the concentrations of oxygen (O2), carbon monoxide (CO), carbon dioxide (CO2), hydrocarbons (HC) and nitrogen oxides NOx. The gas emissions from the engine are recorded simultaneously during engine dynamometer testing using the data acquisition system shown in Figure 5. The torque; RPM; horse power; O2, CO, CO2, HC's and NOx concentrations are measured simultaneously.

Figure 6: Gas Analyzer

3. Results and Discussion

3.1. Quality Assessment of the oil

The free fatty acid content of the WFO was determined by titration with NaOH in the presence of phenolphthalein pH indicator in order to decide which method of transesterification to use. Homogeneous alkaline transesterification is normally recommended for WFO with free fatty acid content below approximately 1-3% [10, 11]. The measured acid value of the WFO before and after water removal (done by heating the oil to ~100°C for 1 hour) was 0.24±0.032 (before) and 0.29 ±0.01 (after) and the measured water content of the WFO 1.21±0.052. Based on the measurements, the FFA content of the WFO was below the requirement to proceed with acid esterification. The average acid value was measured to be 0.24 ml that corresponds to a free fatty acid content of 0.12% suggesting homogeneous alkaline transesterification process. The water content of the oil was measured to 1.2% and removal of the water by evaporation caused a slight increase in acid value to 0.29 ml.

3.2 Biodiesel yield after transesterification

Figure 7 shows the biodiesel yield in transesterification of WFO with methanol using NaOH as catalyst. The best result in transesterification of WFO was achieved with methoxide at high alcohol oil molar fration of 12:1. Actually, at molar ratio of 6:1 the yield decrease significantly from around 90% to 65% when running the transesterification for two hours, and when reaction time was reduced to 1 hours (at this low molar ratio) the reaction was incomplete and a third layer of unconverted saturated fat was observed making separation difficult (Exp.6?). At 12:1 molar ratio the catalyst concentration was examined at 1%, 0.74%, and 0.5%. Similar yields of 90% were achieved at 1% and 0.5% showing that low catalyst concentration can be applied, improving the economy of the process. Decreasing reaction time to 1 hour significantly reduced the biodiesel yield even at high molar ratio.

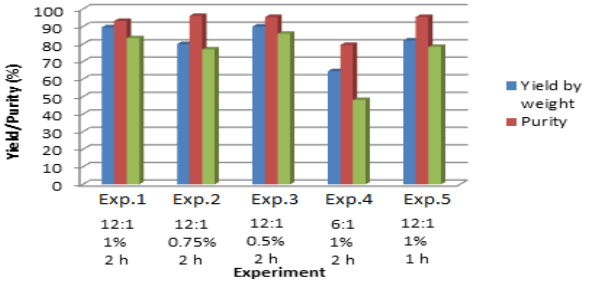

Figure7: WCO biodiesel yield in homogeneous alkaline transesterification at 60°C and continuous stirring.

3.3 Fuel properties of the produced biodiesel

The compositions of FAME in WFO biodiesel were analyzed by gas chromatography and compared with standard grain FAME Mix for peak identification and quantification. Figure 8 shows the chromatogram for WFO biodiesel.

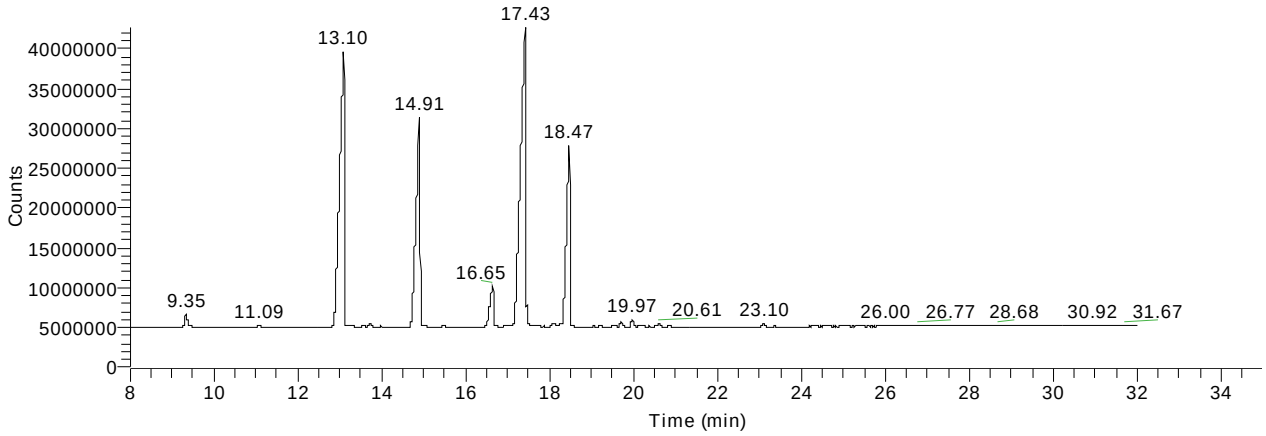

Figure8: Chromatogram of FAME analysis of waste frying oil biodiesel

Fatty Acid Methyl Ester (FAME) composition of WFO biodiesel was identified by comparing the retention times to those of a pure FAME standard mix. Table II? shows FAME-profile (relative % of total peak area). The higher content of Palmitic acid (C16) clearly confirms that the waste oil is based on the palm oil [12].

Table 4: Fatty acid methyl ester (FAME) profile (relative %) of waste frying oil (WCO) biodiesel.

FAME	WCO FAME
C14	1.2
C16	36.9
C18:0	6.7
C18:1	31.6
C18:2	18.9
C18:3	-
C20	0.7
C20:1	0.3
C22	0.3

3.4 Properties Assessment

Table 5 shows the measured fuel properties of the biodiesel produced from waste frying oil.

Table 5: Properties of biodiesel produced from waste cooking oil (WCO) oil at 60 °C using 500 rpm stirring.

Exp.	Flash point (° C)	Density kg/m^3	Viscosity (mm^2/s)	Acid value (mg KOH/g)	Boiling point (° C)	T-90 ° C	Gross heating value MJ/Kg
Exp.1	177	890	4.64	0.79	326	338	40.180
Exp.2	182	843	4.65	0.67	320	346	40.357
Exp.3	179	839	4.72	0.45	320	352	40.137
Exp.4	163	838	4.68	0.73	322	347	40.396
Exp.5	157	842	4.63	0.84	318	340	40.223
Exp.6	unconverted making separation difficult and no yield can be reported for this experiment						
Petro diesel	88	811	3.97	0.22	185	370	45.800

Flash point is the lowest temperature at which vapors from a fuel will ignite on application of a small flame under standard test conditions. A minimum flash point of 130°C for diesel fuel is required for fire safety according to ASTM D93 [5]. Flash point of biodiesel is typically much higher than for petrochemical diesel fuel's (130-170°C ASTM D6751) compared to 60-80°C (ASTM D975) to ensure that the manufacturer has removed excess methanol used in the manufacturing process. Residual methanol in the fuel is a safety issue because even very small amounts reduce the flash point. Residual methanol, which can be found in biodiesel with low, out-of-specification flash point, can also affect fuel pumps, seals and elastomers, and can result in poor combustion properties [5]. In these experiments the flash point for SFO biodiesel varied between 169 and 182oC and for the WFO biodiesel it varied between 157 and 182oC. Most of the sample fall within the requirements of ASTM F6751 but a few samples had higher values. No correlation is observed between the biodiesel yield and the measured flash point.

The density of biodiesel should be 880 kg/m3 according to the ASTM standard and 850 kg/m3 for the petro chemical diesel. The measure densities of the produced biodiesels are 842-890 kg/m3. More tests, especially FAME purity and glycerol content by gas chromatography should be run in order to explain the low density of most of the produced biodiesel samples.

Soot emitted from laminar laminar diffusion flame using biodiesel fuel was also measured. The amount of soot emitted from biodiesel is observed to be much below those emitted by the petrodiesel. To quantify that, an opacity measurement was also conducted as shown in figure 9. Two sets of experiments were carried out with two referenced engine power with a matching pipe diameter. The percentage of the smoke opacity for both set up were nearly one order of magnitude higher for the petrodiesel as shown in table 6.

Table 6: Opacity meter results for biodiesel and petrodiesel.

Fuel	Opacity Value (%) Assuming 100Hp setup			Opacity Value (%) Assuming 200Hp setup		
Biodiesel	1.4	1.3	1.3	1.9	1.4	1.4
Petro diesel	11	19.9	12.2	18.9	23.7	24.6

Figure9: Smoke opacity meter experimental set up.

Biodiesel fuels do not contain aromatics but they contain fatty acids with different levels of unsaturation. Fuels with more unsaturated fatty acids tend to have slightly a lower energy content (on a weight basis) while those with greater saturation tend to have higher energy content [13]. Gross heat of combustion is an important parameter for performance indication. Based on the results shown in table 6, the biodiesel gross heat of combustion values (40.396MJ/Kg) which is less than the value for diesel (45,800 KJ/kg).

3.5 Combustion and emission characteristics of Petroleum Diesel Fuels

Figures 10 and 11 show the engine performance and emissions using conventional petroleum Diesel fuel at different engine speed or rotation per minutes (RPM). The engine starts running at low RPM (~ 1230 RPM) for six seconds after that the RPM of the engine was increased until it reached the maximum value of 3650 RPM. The engine performances (engine horse power and torque) and emissions (CO2, CO, HC and NOX) were recorded for about 18 seconds during this change of the engine RPM. Figure 10 shows that horse power increases from 2.3 HP at low RPM to about 8 HP at high RPM and the torque increases from 10 ft lb at low RPM to about 12 ft lb at high RPM. Figure 11 shows the variation of the engine emissions (CO2, CO, NOX, HCs) with the engine speed or RPM.

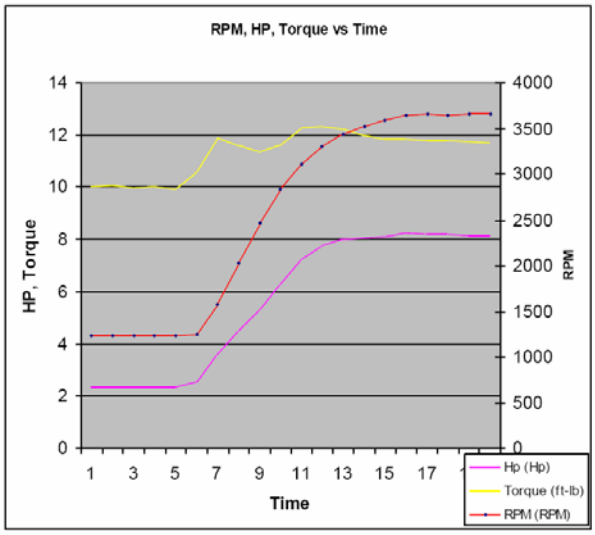

Figure 10: Engine horse power, torque, and RPM versus time (seconds) - Petroleum Diesel fuel

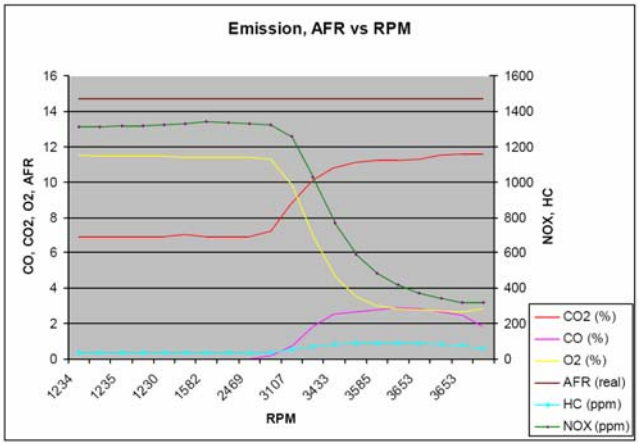

Figure 11: Engine emissions at different RPM - Petroleum Diesel fuel

3.6 Combustion and emission characteristics of Biodiesel Fuel Blends

The Biodiesel fuel produced from waste frying oil WFO and was converted into fuel blends of B5, B10, B15, and B20. The Biodiesel fuel blends are obtained by mixing biodiesel fuel with petroleum Diesel fuel (ex: B5: 5% Biodiesel and 95% Diesel fuel by volume). The waste cooking oil was collected from restaurant located inside the premises of Florida Atlantic University. This restaurant is more focused on deep fried fast food, and the oil is used over and over for up to 3 weeks before it is changed. The procedure for each biofuel combustion test was: (1) the engine was allowed to run for 2 minutes to allow the engine to clear any residue from previous tests with different fuel blends, and warm up the engine and catalyst, (2) after the 2 minutes warm up, the engine was run at high RPM (3550 rpm) for 5 minutes, (3) drop the engine speed to medium RPM (2400 rpm) and run the engine for 5 minutes, and (4) finally set the engine to low RPM (1250 rpm) and run for 5 minutes. The sampling rate was set to 1 Hz. This will produce a total of 300 data points for each RPM. For each Biodiesel fuel blend and for each RPM, the measurement was run at least three times to check the consistency of the data produced. The data produced from these tests includes: Torque

(lbs-feet), Horse Power (HP), Carbon Dioxide CO2 (%), Carbon Monoxide CO (%), Oxygen O2 (%), Hydro Carbon HC (ppm) and Nitric Oxide NOx (ppm). The torque and horsepower readings where measured directly from the dynamometer, while the emissions where obtained from the gas analyzer. The mean value (over 5 minutes) of the diesel engine tests for low, medium and high RPM using petroleum diesel (benchmark) are shown in Table 7. It is noted that the horse power, CO2 and CO emissions increase and the HC and NOx emissions decrease when the speed (rpm) of the engine increases. The baseline data with the petroleum Diesel fuel will be compared to those obtained with Biodiesel fuel blends. Typical results of the Diesel engine tests at high RPM using biodiesel fuel blends (B5, B10, B15 and B20) produced from waste vegetable oil are shown in Table 8. The results show a small change of the engine horse power, torque, CO2 and NOx emissions when the amount of biodiesel blended with petroleum Diesel increases from 5% to 20%. The CO emissions dropped from 0.27% to 0.25% and the HC emissions from 14.06 ppm to 12.14 ppm.

Table 7: Mean value of the Diesel engine tests using petroleum Diesel

RPM	HP	Torque Lbs-feet	CO2 %	CO %	O2 %	HC ppm	NOx ppm
1250	2.34	9.84	7.28	0.02	12.10	33.74	1157
2400	4.50	9.86	7.58	0.02	12.30	30.77	617
3550	7.97	11.80	11.45	0.28	3.98	14.50	398

Table 8: Mean value of the Diesel engine tests at high RPM (3550) using Biodiesel Fuel blends produced from waste vegetable oil

	B5	B10	B15	B20
HP	7.89	7.82	7.80	7.88
Torque, Lbs-feet	11.71	11.66	11.58	11.49
CO2 %	11.68	11.70	11.60	11.43
CO %	0.27	0.26	0.259	0.25
O2 %	3.55	3.50	3.49	3.47
HC ppm	14.06	13.18	12.82	12.14
NOx ppm	398	402	405	406

Figure 12 shows the percentage difference of the data obtained with the biodiesel fuel blends and the petroleum diesel fuel. The results show a net decrease of the Hydrocarbons HC and CO emissions for the B20 biodiesel fuel blend compared to the petroleum diesel fuel. Biodiesel fuel contains fewer hydrocarbons than those present in petroleum diesel. It is natural to expect a decrease in HC emissions as the blends increase [14]. The Hydrocarbons emissions for the B20 decreases by about 20% compared to the petroleum Diesel fuel. The carbon monoxide emissions decrease by about 12 % for the B20. Although the hydrocarbon HC and CO emissions decreased drastically, a small change (< 2%) of the engine power HP and CO2 emissions are reported for the B20 compared to the petroleum Diesel fuel. The NOx emissions also increase by about 2% for the B20. This is due probably to an increase of thermal NOx because of the combustion temperature increase for the B20 [15].

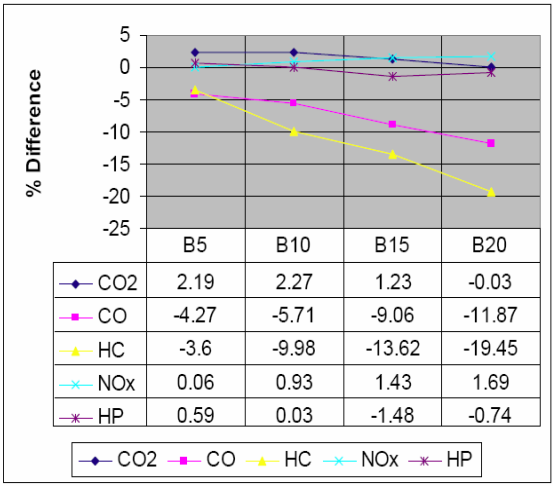

Figure 12: Overall percentage differences of biodiesel fuel blends with respect to petroleum Diesel

4. Conclusions

Biodiesel was produced from WFO collected from local restaurants and subjected to transesterification. As the free fatty acid content of the waste oil was 0.12% which is below the 3% threshhold, a homogeneous alkaline transesterification was pursed in this work. Transesterification of waste cooking oil was examined for molar alcohol to oil ratio of 12:1 and 6:1, catalyst concentrations of 0.5, 0.75, and 1%, and reaction times of one and two hours. The best results for WFO were achieved with high alcohol molar ratio of 12:1, 1% and 0.5% catalyst, two hours continuous mixing reaction time. A significant drop in yield was observed at low molar ration of 6:1 or blow one hour processing time. The purity of the produced biodiesel determined by gas chromatography was 95% at optimal conditions (0.5% NaOH, 12:1 molar ratio, for 2 hours).The measured fuel properties of the produced biodiesel samples fell within the requirements of American Standard for biodiesel fuel suggesting the viability of the process and its scale up for mass production. Biodiesel fuel blends (B5, B10, B15 and B20) were prepared by mixing the biodiesel fuel with Petroleum Diesel. The biodiesel fuel blends were tested on the Diesel Engine and the results were compared to those obtained with Petroleum Diesel Fuel. The results obtained in this study show that the hydrocarbons HC and CO emissions decreased by increasing the amount of biodiesel blended with Petroleum Diesel. The HC and CO emissions decreased respectively by 20 % and 12 % for the B20 compared to the Petroleum Diesel while the NOx emissions increased by 2% and the change of the engine power was negligible (<2%).

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