Study on the Production of Biodiesel from Sunflower Oil

Aye Hnin Khine[1], Aye Aye Tun[2]

[1]Department of Chemistry, Yangon University, Myanmar; ahkhine2012@gmail.com
[2] Dagon University, Myanmar; ayeayetun1961@gmail.com

Abstract. Feasibility study on the production of biodiesel from sunflower oil by the alkali-catalysed transesterification method was done. The physicochemical properties of sunflower oil were firstly evaluated. Reaction parameters such as the reaction time, the amount of catalyst, the volume ratio of alcohol to oil, temperature and rate of mixing were found to significantly influence the yield and viscosity of biodiesel. The optimum conversions of sunflower methyl ester(SFME) from sunflower oil(SFO) were achieved by using NaOH catalyst 0.5 % w/v, methanol to oil volume ratio 0.25, reaction temperature 60 ºC , rate of mixing 600 rpm for a period of 3 hours. The fuel properties of SFME produced under the optimum condition were in agreement with all prescribed ASTM international biodiesel specification. GC-MS revealed that methyl linoleate, methyl oleate, methyl palmitate and methyl stearate were major components of SFME. The engine performance tests on prepared biodiesel revealed that it can be substituted in some part of petroleum diesel.

Keywords: biodiesel, sunflower oil, alkali-catalysed transesterification, sunflower methyl ester
PACS: 88.85.mb

INTRODUCTION

Biodiesel is a diesel fuel substitute that is produced from renewable sources such as vegetable oils, animal fats and recycled cooking oil. Chemically, it is defined as the monoalkyl esters of long chain fatty acids. The performance of vegetable oil as diesel fuel depends on the chemical composition of the plant oil particularly on the carbon chain length and the degree of saturation and unsaturation of fatty acid molecules. There are at least four ways in which oils and fats can be converted into biodiesel, namely, transesterification, blending, micro-emulsions and pyrolysis. Among these methods, transesterification is the most commonly used method [1, 2].

Transesterification is one of the reversible reactions and proceeds essentially by mixing the reactants such as alcohol and triglyceride. However, the presence of a catalyst (a strong acid or base) accelerates the conversion.

In this paper, biodiesel was produced by transesterification of sunflower oil (SFO) under various conditions. The optimum condition was investigated by varying the reaction time, amount of catalyst, volume ratio of alcohol to oil, reaction temperature and rate of mixing. These parameters significantly influenced the yield and viscosity of biodiesel.

The potential environmental benefits of using biodiesel instead of petroleum derived diesel include a reduction in the generation of greenhouse gases. It is also a very low sulphur fuel, reducing acid rain. Biodiesel is biodegradable and in the event of a fuel spill there are fewer long-term environmental effects compared to petroleum products. Biodiesel can be produced from domestic feedstock. Materials only need to be transported locally, thus, reducing the energy consumption, and corresponding pollution, required to manufacture the fuel [3].

MATERIALS AND METHODS

Sample collection

Sunflower oil was purchased from Kyauktan Township, Yangon Division in Myanmar. After being received, the sample was kept in the sealed airtight container and placed in a cool and dark place.

Production of biodiesel from sunflower oil at optimum conditions

Biodiesel was produced by alcoholysis of sunflower oil under various conditions. The optimum condition was investigated by varying the reaction time, the amount of catalyst, the volume ratio of alcohol to oil, reaction temperature and rate of mixing. Production of sunflower methyl ester (biodiesel) at optimum condition was as follows.

25 mL of methanol (*i.e.*, 0.25 v/v methanol-to-oil ratio) was placed into a three-necked round bottomed flask. Each neck was fitted with a condenser, a thermometer and a N_2 gas inlet respectively. Sodium hydroxide catalyst (0.5 % w/v of oil) was added. It was heated at 60 ºC and stirred at a speed of 600 rpm until all sodium hydroxide was dissolved. This solution was flushed with N_2 gas for 5 minutes. 100 mL of sunflower oil was then added under stirring and heating. The reaction was continued for 3 hours.

After reaction, the mixture was carefully transferred to a separating funnel and allowed to stand overnight to separate biodiesel from glycerol layer. To obtain pure biodiesel, the upper biodiesel layer was evaporated in rotary evaporator and washed with warm water for several time. The moisture from washed biodiesel was removed by standing over anhydrous sodium sulphate and then filtered. The biodiesel so as to obtain was denoted as SFME.

Determination of the fuel properties of prepared biodiesel

Fuel properties such as kinematic viscosity, specific gravity, acid value, flash point, pour point, cetane index, Conradson carbon residue, copper strip corrosion, water and sediment were determined by ASTM D6751 method [4] and AOCS official method [5].

Characterization by GC-MS

The fatty acid composition of prepared biodiesel (SFME) was determined by GC-MS analysis. GC-MS spectrum of prepared biodiesel was recorded by GC-MS spectrometer at the Department of Chemistry, Ben-Gurion University of Negev, Israel.

Engine performance test

The engine performance tests were carried out in single cylinder, Kubota (KND 5B 114627) diesel engine and Sichuan (EMEI 185-1) diesel engine at No(2) Machine Tools Factory, Ministry of Industry(2), Hlaing Township and Myanmar Railway, Railroad Engine Factory, Ministry of Rail Transportation, Pa Zun Daung Township, Yangon.

RESULTS AND DISCUSSION

Physicochemical properties of sunflower oil (SFO)

Physicochemical properties of sunflower oil were shown in Table 1 along with the literature values reported from the works of different researchers. The specific gravity and kinematic viscosity of oil were important that indicated the degree of conversion of vegetable oil to methyl ester (biodiesel). Acid value, FFA content, iodine value, peroxide value, saponification value and unsaponifiable matter were also important to determine the quality and stability of oil.

TABLE 1. Physicochemical properties of sunflower Oil (SFO)

No	Physicochemical properties	Values	Literature values
1	Specific gravity at 60º/60º F	0.92	0.900-0.926
2	Kinematic viscosity at 40 ºC	33.86	33.9
3	Acid value (mg KOH/g)	1.68	0.6-2.4
4	Free fatty acid, FFA (%)	0.84	0.15-1.0
5	Iodine value (cg I_2/g)	107.08	88-140
6	Peroxide value (meq/kg)	5.93	0.75-8.0
7	Sponification value (mgKOH/g)	188.82	180-200
8	Unsponifiable matter (%)	1.05	1.5
9	Molecular weight (g mol^{-1})	891.32	876-890
10	Average molecular weight	284.42	280

Production of sunflower methyl ester (biodiesel) from sunflower oil (optimization of reaction condition)

Sunflower methyl ester (SFME) was produced by methanolysis of sunflower oil in the presence of sodium hydroxide catalyst. The experimental variables examined in the study were NaOH (catalyst) concentration (0.2 %, 0.5 %, 0.8 %, 1.0 % and 1.3 % w/v of oil), MeOH/oil ratio (0.20, 0.25, 0.30, 0.40, and 0.50 v/v), reaction time (0.25, 0.50, 1, 2, 3, 4 and 5 h), reaction temperature (30, 45, 60, and 70 ºC) and mixing intensity (240, 360, 480, 600, 720, and 840 rpm).

Optimum condition in this work was established on the basic of not only biodiesel yield but also viscosity of that biodiesel. Viscosity sometime used as an indicative of purity of that biodiesel. In addition, the difference in viscosity between the parent oil and the alkyl ester derivative can be used to monitor the progress of biodiesel formation [6]. The yield of biodiesel was calculated as volume basic and reported as % vol. The optimum conditions were: 0.25 v/v methanol to sunflower oil, 0.5 % (w/v of oil) of NaOH catalyst, 60 ºC reaction temperature, 3 h reaction time and 600 rpm mixing intensity.

Employing aforementioned optimum condition provided SFME in high yield (87 % vol) within prescribed ASTM D6751 specification.

Determination of the fuel properties

In the preparation of biodiesel, *i.e.*, during the transesterification reaction, small amount of reactants and by products, including water, free fatty acid (FFA), catalyst, residual alcohol, unsaponifiable matter, and soaps may contaminate the final product. These minor components may cause severe operational problems, such as engine deposits, filter clogging, or fuel deterioration. Therefore, American Society for Testing and Materials (ASTM) standard are in place to restrict the amount of most minor components that can affect the biodiesel quality. The fuel properties of prepared biodiesel (SFME) were in agreement with all prescribed ASTM international biodiesel specification. The fuel properties of SFME, and diesel fuel are shown in Table 2.

TABLE 2. Fuel properties of prepared biodiesel (SFME) and diesel fuel

Properties	Units	SFME	Diesel
Specific gravity at 60º/60º F	-	0.8829	0.8434
Kinematic viscosity at 40 ºC	cSt	4.29	3.60
Acid number	mg KOH/g	0.42	-
Flash point	ºC	92	70
Pour point	ºC	0	0
Cetane index	-	46.62	54.0
Copper strip corrosion	-	No.1(a)	No.1(a)
Conradson carbon residue	% wt.	0.01	0.03
Water and sediment	% vol.	trace	-
Yield % of liquid fuel	% vol.	87	-

Characterization by GC-MS

GC chromatogram revealed the fatty acid composition in the sample by simply examining the number of peaks at their respective retention times. The interpretation of peak could be done by matching with mass spectra that has been already stored in library (by library search).

It is essential to know the fatty acid of prepared biodiesel since the fatty acid profile affect the fuel properties of that biodiesel. Ideally, the vegetable oil should have low saturation and low polyunsaturation, *i.e.*, be high in monounsaturated fatty acid. Vegetable oil that rich in polyunsaturated tent to have poor oxidation stability and vegetable oil with high degree saturation tend to have poor flow characteristics.

According to the result from GC-MS, the major fatty acids present in sunflower oil were: (i) C 18:2 linoleic acid (46.18 %), (ii) C 18:1 oleic acid (25.43 %), (iii) C 16:0 palmitic acid (8.47 %) and (iv) C 18:0 stearic acid (7.14 %). (Table 3 and Figure 1)

TABLE 3. Fatty acid profile of SFME (analyzed by GC-MS)

Retention time (min)	Area (%)	Identification of compound
35.70	8.47	C 16:0
40.35	46.18	C 18:2
40.54	25.43	C 18:1
41.07	7.14	C 18:0

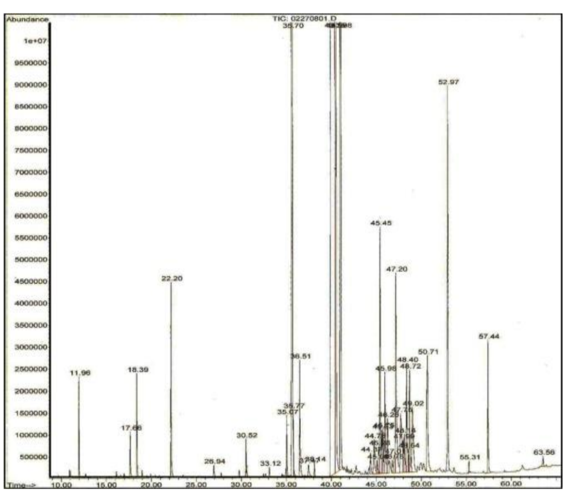

FIGURE 1. GC spectrum of sunflower methyl ester (SFME)

Engine performance test of prepared biodiesel (SFME)

Kubota diesel engine has a power of 4.5 kW (6 hp) normal engine running power and working power of 3.7 kW (5hp) with a maximum revolution of 2000 rpm. The testing was conducted at a revolution of 1800 rpm. It was found that about 0.48L of biodiesel was consumed for the one- hour operation of engine at 1800 rpm without load (0.42 kg/h) whereas 0.64L of diesel fuel (MPPE) was required for one hour run under same condition (0.54 kg/h). The water tank temperature was found to be 95 ºC.

Sichuan diesel engine has a power of 6.62 kW (9 hp) normal engine running power and working power of 5.88 kW (8 hp) with a maximum revolution of 2200 rpm. The testing was conducted at a revolution of 1500 rpm. It was found that about 0.52 L of B100 was consumed for the one-hour operation of engine at 1500 rpm without load (0.46 kg/h) whereas 0.72 L of diesel fuel (MPPE) was required for one hour run under the same condition (0.61 kg/h). The prepared biodiesel was found to operate smoothly those engines and exhibited no starting problems. The fuel consumption rates were different depending on the type of diesel engine and biodiesel provided as good performance as diesel fuel. The results were shown in Table 4 and Table 5.

TABLE 4. Engine performance test of SFME (KUBOTA diesel engine)

Fuels	Revol-ution (rpm)	Water temp. (ºC)	Fuel consump-tion (kg/h)	Observa-tion
SFME	1800	95	0.42	Smooth running
Diesel	1800	95	0.54	Smooth running

TABLE 5. Engine performance test of SFME (SICHUAN diesel engine)

Fuels	Revol-ution (rpm)	Water temp. (ºC)	Fuel consump-tion (kg/h)	Observa-tion
SFME	1500	95	0.46	Smooth running
Diesel	1500	95	0.61	Smooth running

CONCLUSION

Sunflower oil (SFO) exhibited good physicochemical properties that suited as biodiesel feedstock. The optimum reaction conditions for transesterification were: methanol/oil volume ratio of 0.25, NaOH catalyst 0.5 % w/v, reaction temperature 60 ºC, mixing rate 600 rpm and reaction period of 3 hours. Under these conditions, 87 % vol. of sunflower methyl ester (SFME) in high purity was isolated. The fuel properties of sunflower methyl ester (SFME) were in agreement with all prescribed ASTM international biodiesel specification. GC-MS revealed that linoleic acid, oleic acid, palmitic acid and stearic acid were major fatty acids of SFME. Sunflower oil has low contents of saturated fatty acid and is suitable source for biodiesel production. The engine performance tests were conducted and it was found that fuel consumption rate of biodiesel was lower than that of diesel fuel. The engine operated smoothly and the biodiesel behaved as good performance as diesel fuel. Therefore, biodiesel prepared from sunflower oil can be used as a diesel substitute for all diesel engines without any modification of those engines.

REFERENCES

1. F. Ma and M.A. Hanna, "Biodiesel Production: A Review", *Bioresource Technol.*, **70**, (1999), pp. 1-15.
2. A. Srivastava and R. Prasad, "Triglycerides-Based Diesel Fuel", *Renew. Sustain. Energy Rev.*, **4,** (2000), pp. 111-133.
3. B. Elliott, "Low-Cost Biodiesel Production Process Using Waste Oils and Fats", U.S. EPA SBIR Phase 1 Kick-Off Meeting, Washington, DC, (April 5-6, 2007)
4. Annual Book of ASTM Standards, "Petroleum Products, and Lubricants", **5** (01), D56-D1660, USA, 1985.
5. E.M. Sallee, "Official and Tentative Method of the American Oil Chemists Society", *AOCS*, 2nd Ed., the Procter and Crumble Company, Cincinnati, Ohio, 1958.
6. P.D. Fillipis, C. Giavarini, M. Scarsell, and M. Sorrentino, *J. Am.Oil. Chem. Soc*., **71**, (1995), p. 1399.