Contemporary Engineering Sciences, Vol. 7, 2014, no. 22, 1163 - 1170
HIKARI Ltd, www.m-hikari.com
http://dx.doi.org/10.12988/ces.2014.49145

The Various Analysis on Characteristics of BD from Animal Fats

Seunghun Choi

Department of Automation Mechanical Engineering
Vision University of Jeonju
Jeonju, 560-760, Korea

Youngtaig Oh

Department of Mechanical Engineering
Research Center of Industrial Technology
Chonbuk National University, Jeonju, 561-756, Korea

Abstract

This paper evaluated overall properties of biodiesel (BD) from lard and beef tallow, based on analytical methods of gas chromatography analysis and Fourier Transform Infrared (FTIR) spectroscopy. This study also investigated the effects of BD properties on spray formation characteristics, at various injection pressures and particle size distributions, of the exhaust gas from a diesel engine. The results of analytical experiment indicated that the animal fat BD mainly consists of saturated fatty acids. Therefore, alternative fuel with high cetane number can be produced from animal fats. Compared with diesel fuel, animal fat BD has shown different spray patterns and smoke emission particle distributions. Sauter Mean Diameter (SMD) was slightly higher for BD droplets, while smoke particle size and density after the burning of droplets decreased for BD blends, due to more complete combustion. On the whole, it is concluded that the animal fat BD properties were in reasonable agreement with the international ASTM D6751, EN 14214 and Korean national standards of BD.

Keywords: Renewable energy, Animal fat, Biodiesel, Chromatography, Spect roscopy, FTIR

1 Introduction

Our previous study has investigated high quality BD production from lard, by using solvent additive[1]. In the last ten years, the quality control of BD has drawn a great deal of attention, from many researchers[2]. Various analytical methods have been tried, for analyzing BD properties. The commonly used analytical methods for analyzing BD are chromatography, and spectroscopy. Gas chromatography (GC) is the most widely used method, due to its higher accuracy and shorter time. Several researchers have used FTIR spectroscopy, to monitor the quality of BD. The results of our literature review have indicated that a complete analysis of lard and beef tallow (beef-T) BD properties has not yet been investigated in detail.

In the present study, the overall physical and chemical properties of BD from lard and beef-T are analyzed, by using GC, and FTIR analysis. Also, this research comparatively investigates the direct effects of BD properties on the spray characteristics of experimental fuels, and the particle size distribution of exhaust smoke, after burning of injected fuels.

2 Material and Methods

Commercial purified lard and beef-T was provided by Samyang (South Korea), and used without any further purification. Methanol (99.5 wt.%), potassium hydroxide powder (95 wt.%) and hexane were purchased from Samchun Pure Chemical Co., Ltd. (South Korea). The animal fat BD was produced by the same method as described in a previous study[3]. All properties of BD were analyzed by the Korean Institute of Petroleum Management (Table 1), and BD properties were in reasonable agreement with the ASTM D6751 and EN 14214 standards. The predicted cetane numbers of BD samples, described in Table 1, were calculated according to Ramos et al.[3] and Bamgboye and Hansen[4].

A spray system was used to analyze the spray behavior of experimental fuels. This equipment consisted of injectors, an injector trigger, fuel supply equipment, and a laser diffraction particle analyzer (LDPA-Sympatec KF-Vario/ Germany). The injection pressure was varied from 400~800 bar, at 100 bar intervals. Fatty acid methyl esters (FAMEs) composition in samples of animal fat BD was analyzed by gas chromatography (GC/MS-QP2010 Ultra). The chemical functional groups of experimental fuels were determined by FTIR spectrum (Spectrum GX/Perkin Elmer). The test engine used in this experiment was a single cylinder, water-cooled diesel engine (ND130). Particle samples of the experimental fuels were collected on filter paper by smoke meter (Hesbon-HBN1500/ Korea), until the smoke opacity reached to about 80%. Scanning electron microscopy (SEM, JSM-5900, JEOL Ltd., Japan) was used to obtain digital images of the collected particles. The images obtained by SEM (3000 magnification) were subjected to a digital treatment developed in Image-J software.

Table 1. Properties of BD from animal fats

	Lard BD	Beef-T BD	ASTM D6751-09	EN 14214
Density, (kg/m^3)	858	834	-	860~900
Viscosity, (mm^2/s)	3.1	2.7	1.9~6.0	3.5~5.0
Cetane number	61.1	63.9	>47	>51
Flash point, (°C)	140	140	>130	>120
Pour point, (°C)	2.0	5.0	-15 to 10	-
CFPP, (°C)	-2.0	4.0	-3~12	-5~20
Heating value, (MJ/kg)	40.04	40.9	-	-
Carbon residue, (wt.%)	0.01	0.01	<0.05	<0.3
Sulfur, (mg/kg)	2.0	1.0	<0.05	<10
Sulfated ash, (wt.%)	0.001	0.001	<0.02	<0.02
Total glycerin, (wt.%)	0.076	0.058	<0.24	<0.25

3 Results and discussion

Figure 1 shows the SMD and span factor (SF) of the droplet size distribution, according to the experimental fuels and injection pressures. It can be seen that the SMDs of animal fat BD were slightly higher than those of diesel fuel, because of higher viscosity. The maximum increase rate of SMD in this study was only 2.8 % for beef-T BD, in comparison with the baseline data of diesel fuel. At low injection pressure, a slightly high SF value of animal fat BD was signified, and the spray size was distributed at a low range. But, the SF was similar between diesel and animal fat BD at high injection pressure.

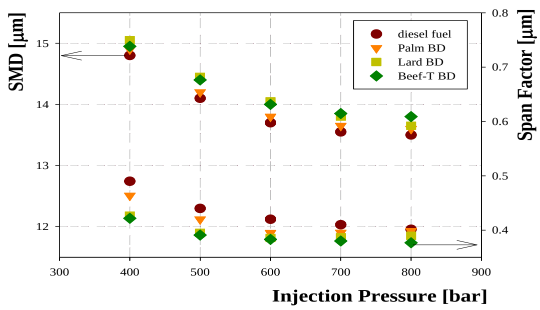

Fig 1. Variation of SMD and span factor of experimental fuels

Figure 2 shows the droplet size distribution, and the accumulation volume of experimental fuels versus injection pressures. The accumulation volume distribution moved toward the small droplet size direction, for animal fat BD. High volume frequency was observed with spray sizes of 13~15 and 15~17 μm for animal fat BD and diesel fuel, respectively at low injection pressure. The small sized droplets increased, and the large sized droplets decreased, for animal fat BD, compared with those of diesel fuel. At high injection pressures, animal fat BD indicated a similar volume frequency distribution, and the peak point of maximum frequency particle size was about 14 μm, for all experimental fuels.

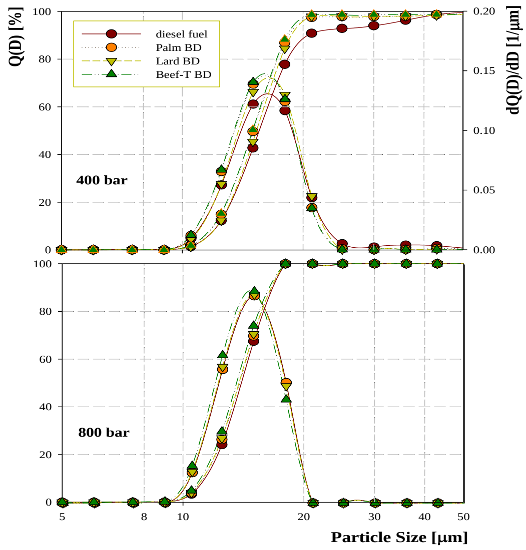

Fig. 2 Droplet size distribution of experimental fuels

Figure 3 shows a GC/MS analysis of the BD samples from animal fat s. The main FAME compositions of BD samples are presented in Table 2. FAME profiles for the animal fat BD were generally similar to each other. The main difference is that the beef-T BD contains more SFA than that of lard BD. In beef-T BD, the SFA component accounts for almost 53 % of the total fatty acids. The main difference between animal fat and vegetable oil based BD is the FAMEs composition.

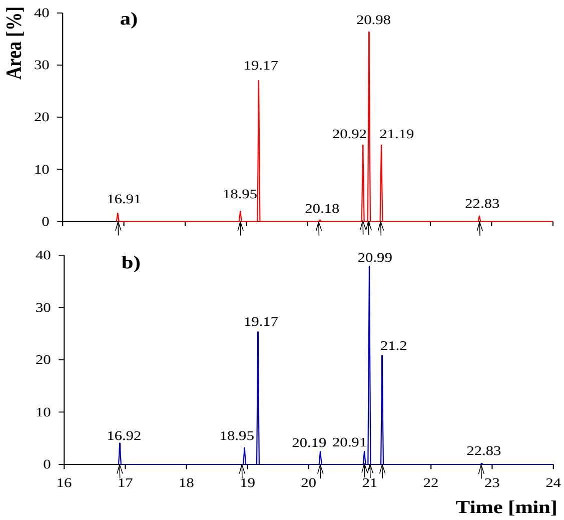

Fig.3 Gas Chromatogram of animal fat BD

Table 2. The FAMEs composition of animal fat BD

FAME, [wt.%]	Lard BD	Beef-T BD
Myristic, (C14:0)	1.61	4.08
Palmitic, (C16:0)	27.04	25.37
Palmitoleic, (C16:1)	1.99	3.21
Heptadecanoic, (C17:0)	0.34	2.48
Stearic, (C18:0)	14.66	20.85
Oleic, (C18:1)	36.37	37.9
Linoleic, (C18:2)	14.66	2.49
Linolenic, (C18:3)	-	-
Eicosenoic, (C20:0)	1.05	0.22
Total	97.7	96.6
Saturated (SFA)	44.7	53
Unsaturated (UFA)	53.02	43.6
SFA/UFA	0.84	1.21

The vegetable oil BD has high content of UFAs,[5] while animal fat BD contains more amounts of SFAs. Higher SFAs composition leads to much higher CN[5]. Rapeseed and soybean BD show generally lower values of CNs (55 and 49, respectively)[6]. Therefore, the most advantage of animal fat BD was the much higher CN (Table 1). The FTIR spectra of animal fat BD and diesel fuel are shown in Figure 4. The spectra are sensitive to the physical and chemical states of individual constituents, in a sample between wave numbers of 400 and 4000 cm^{-1}.

FTIR represents the spectrum of absorption of all the chemical bonds, such as C–H, C=O, C–O. There are no spectrum peaks of any samples in the regions (1750~2800 cm^{-1}) and (3020~4000 cm^{-1}), while all samples absorb well in those regions.

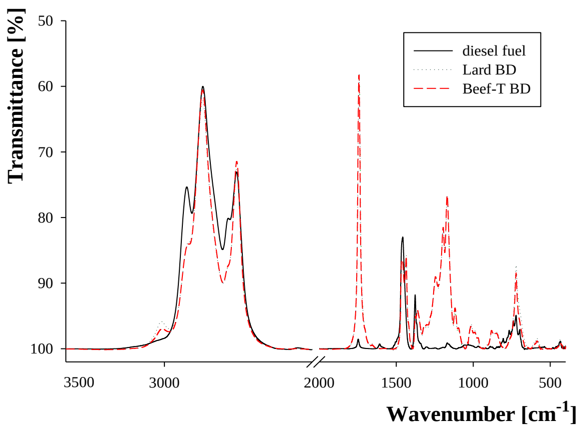

Fig.4 FTIR spectra of experimental fuels

The FTIR spectra of lard and beef-T BD are, as expected, very similar, since the two compounds have almost the same chemical groups. The band due to C–H stretch bonds of saturated carbons vibration shows multiple peaks at 2850~3010 cm^{-1}, in all samples of diesel and animal fat BD. In the FTIR spectrum, many differences were found in the spectra of BD and diesel fuel, such as the large difference in the peak arrangement between the regions of 1700 to 1800cm^{-1}, and 1000 to 1250 cm^{-1}. A most important spectral FTIR range was 1735~1750 cm^{-1} for BD, where the absorption peak corresponds to the carbonyl group vibrations. Both lard and beef-T BD samples contained an ester group that was indicated in the FTIR spectrum by a strong carbonyl signal of 1742 cm^{-1}. However, the peak of this functional group was weak for diesel fuel, and the peak position changed to 1747 cm^{-1}. All samples of diesel and animal fat BD absorb in 1350 to 1500 cm^{-1}, which correspond to angular deformation of CH_2 and CH_3. The "fingerprint" region (900~1200 cm^{-1}) of complex spectra includes many coupled vibration bands. A significant spectral difference can be observed between 1000 and 1250 cm^{-1}, where the absorption peak corresponds to the stretching of the C–O bonds of alcohol groups, present only in BD samples. Peaks in the region (740~900 cm^{-1}) are assigned to symmetric angular deformation, out-of-plane of the C–H bonds of olefins. The peak at 725 cm^{-1} in the FTIR spectrum of BD may be attributed to the asymmetric H–C–H angular deformation of the $(CH_2)n$ long chains[7,8].

Representative SEM images of collected particles from experimental fuels are given in Figure 5. The individual particle shape was spherical for all kinds of samples, and particles were agglomerated in a filter paper cavity. Compared with diesel fuel, lard BD significantly reduces the particle size, which can mainly be attributed to the higher oxygen content of BD (Figure 6).

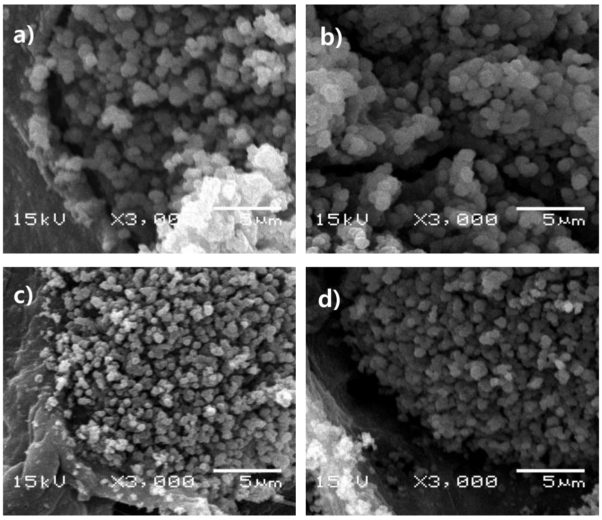

Fig.5 SEM images of particles collected in the filter paper from experimental fuels. a) diesel fuel; b) lard BD30; c) lard BD50; and d) lard BD70

The results indicated that most of the emitted particles were in the size range of 450-550 nm for lard BD70, while they were 700-800 nm for diesel fuel. The reduction rates of smoke particles mean diameter were 28 % for lard BD 70~30, compared with the baseline data of diesel fuel.

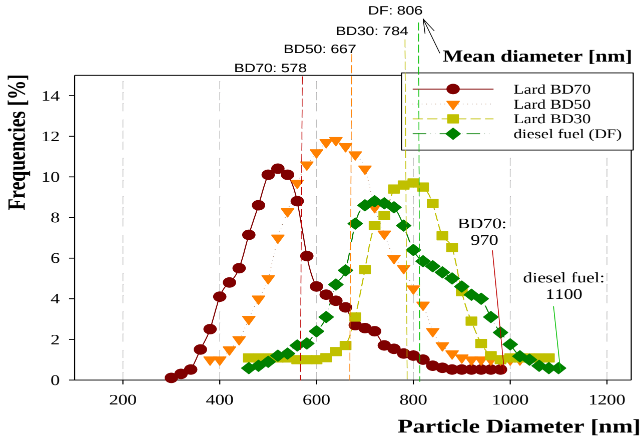

Fig.6 Particle number and size distribution of experimental fuels

4 Conclusion

From the result of analytical analysis, the FAMEs composition and chemical functional group structures of lard and beef-T were very similar to each other. The main difference between animal fat and vegetable oil based BD was the FAMEs composition. Vegetable oil BD has high content of UFAs, while animal fat BD contains more amounts of SFAs. Hence, alternative fuel with higher CN can be produced from animal fats. However, animal fat BD has unfavorable characteristics of cold-temperature properties, because of the higher palmitic and stearic acids content. BD blending rate in a diesel fuel leads to increase in the SMD of injected droplets, whereas smoke density and particle size decreased significantly, due to higher oxygen content, and more complete burning of BD. Furthermore, this study result indicates animal fats can be an interesting low-cost alternative feedstock to produce high quality BD, and animal fats have a great potential to increase the BD production amount.

Acknowledgment. This research work was supported by the Basic Science Research Program, through the National Research Foundation of Korea (NRF), funded by the Ministry of Education, Science and Technology (No.1301000926).

References

[1] Azjargal J., Oh Y.T., Choi S.H., High quality biodiesel production from pork lard by high solvent additive, *ScienceAsia*, **38** (2012), 95-101.

[2] Zhang W. Review on analysis of biodiesel with infrared spectroscopy, *Renewable and Sustainable Energy Reviews*, **16** (2012), 6048–58.

[3] Oliveira J.S., Montalvao R., Daher L., Suarez P.A.Z., Rubim J.C., Determination of methyl ester contents in biodiesel blends by FTIR-ATR and FTNIR spectroscopies, *Talanta*, 69, **127** (2006), 8–12.

[4] Allen C.A.W, Watts K.C., Comparative analysis of the atomization characteristics of fifteen biodiesel fuel types, *Am Soc Agric Engrs*, **43(2)** (2009), 207–11.

[5] Knothe G., Matheaus A.C., Ryan T.W. Cetane numbers of branched and straight-chain fatty esters determined in an ignition quality tester, *Fuel*, ***82*** (2003), 971–75.

[6] Lapuerta M., Fernandez J.R., Mora E.F., Correlation for the estimation of the cetane number of biodiesel fuels and implications on the iodine number, *Energy Policy*, **37** (2009), 4337–44.

[7] Lira L.F.B., Albuquerque M.S., Pacheco J.G.A. Fonseca T.M., Cavalcanti E.H.S., Stragevitch L., Pimentel M.F., Infrared spectroscopy and multivariate calibration to monitor stability quality parameters of biodiesel, *Microchemical Journal*, **96** (2010), 126–31.

[8] Choi S.H., Oh Y.T., Evaluation of Biodiesel from Animal Fats by Gas Chromatography, FTIR Spectroscopy and Spray Behavior, *Advanced Science and Technology Letters*, **58**(2014), 133-136.

Received: August 03, 2014