Journal of Scientific & Industrial Research
Vol. 79, January 2020, pp. 81-83

Effect of TBHQ on the Combustion Characteristics of Pomelo oil Biodiesel in a Compression Ignition Engine

Madhurjya Saikia[1]*, Dilip Kumar Bora[2] and Kalyan Kalita[3]

[1]Mechanical Engineering Department, Dibrugarh University, Dibrugarh-786004, Assam
[2,3]Mechanical Engineering Department, Assam Engineering College, Ghy-781001, Assam

Received 28 May 2018; revised 16 June 2019; accepted 12 October 2019

Biodiesel is a biomass-based fuel. Biodiesel faces the difficult issue of storage stability. The storage stability of a biodiesel can be enhanced by adding an antioxidant to the fuel, which represses oxidation reactions that take place upon exposure to sunlight, heat, moisture, humidity, and metal. In the present study, biodiesel is synthesized from pomelo oil (*Citrus maxima*) and treated with a synthetic antioxidant called TBHQ (Tertiary butyl hydroquinone). The engine and emission performance of the biodiesel with TBHQ in various concentrations have been determined in a single cylinder four stroke diesel engine. It is observed that brake specific fuel consumption increases with the increasing concentration of TBHQ. Brake power stays unaltered for the biodiesel with or without TBHQ. Considerable reduction in carbon monoxide and carbon dioxide has been observed for biodiesel irrespective of antioxidant treatment.

Keywords: Biodiesel, TBHQ, Antioxidant, BSFC, BTE, BP, CO, CO_2

Introduction

Biodiesel can be obtained from any vegetable oil or animal fat by transesterification process[1, 2]. Biodiesel comprises long-chain double bonded fatty acid molecules. The introduction of biodiesel to heat and air fastens the oxidation of biodiesel, converting fatty acids to allylic hydro peroxides, aldehydes and, acids[3,4]. Oxidation of biodiesel influences fuel of sunflower, canola, and animal fat, Mittelbatch and properties such as the acid value, peroxide value, viscosity, and iodine value and hence, compromise storage stability[4]. Applying antioxidants like PY (Pyrogallol), PG (Propyl gallate) and TBHQ (Tertiary butyl hydroquinone) on methyl esters Schober have observed an improvement in storage stability[5]. Applying the same antioxidants to soybean biodiesel as the former authors, Dunn *et al*. has reported the same[6]. On the other hand, PY is appropriate for biodiesel synthesized from poultry fat, jatropha, Croton, Pongamia and cotton oils [7-10]. Ryu has studied the engine and emission performance of the soybean biodiesel with BHT (Butylated hydroxyl toluene), BHA (Butylated hydroxyl anisole), and TBHQ (Tertiary butyl hydroquinone) and has reported that the brake specific fuel consumption increases, but emissions levels remain the same for biodiesel with or without antioxidants [11]. There are ample examples of antioxidant treated biodiesel synthesized from Croton, jatropha, canola and palm oils, which show appreciable reductions in BSFC compared to the untreated ones[8-11]. This study seeks to find how TBHQ as an antioxidant in varying concentration (1000 to 4000 ppm) to pomelo oil biodiesel may influence its engine performance and emission performance in a single cylinder four stroke diesel engine.

Material and methods

The biodiesel has been prepared from pomelo seed oil (*Citrus maxima*) by transesterification. In the process, the vegetable oil is reacted with methyl alcohol in the presence of potassium hydroxide (KOH). The mixture is agitated at 300 RPM on a magnetic stirrer and held at 60ºC for 90 minutes. Then, the mixture is rested for 12 hours in a separating flask. After 12 hours, two distinct layers form in the flask: the top layer of biodiesel and the bottom layer of glycerol. The biodiesel is separated from the glycerol by gravity separation method. Several warm water washes have been given to biodiesel to remove traces of KOH and alcohol. The properties of the resultant biodiesel are evaluated according to ASTM D6751 standards and are summarized in table 1. Five test fuels have been prepared by adding the TBHQ in quantity of 0, 1000,

*Author for Correspondence
E-mail: madhurjyasaikia3@gmail.com

2000, 3000 and 4000 PPM by weight and stored properly in glass vessels. The engine performance of the test fuels has been evaluated in a single cylinder, four-stroke, water-cooled Kirloskar diesel engine of 3.7 kW having the operating temperature of the water maintained at 70±5 º C all the time. The fuel filter and engine oil have been replaced after every test run.

Results and Discussion

Engine performance

Figure 1 shows the effect of TBHQ on the brake specific fuel consumption (BSFC) of Pomelo oil biodiesel containing 1000 to 4000 ppm of the antioxidant respectively. The BSFC of the biodiesel with or without antioxidant is always higher than that of diesel owing to lower calorific value. In the case of biodiesel, the engine consumes more fuel in order to maintain the same power output. The BSFC of base biodiesel is found to be 7.05 per cent higher than that of diesel at the highest load. Though antioxidant lengthens the storage stability of biodiesel, it reduces the calorific value of the fuel. Due to this factor, the biodiesel samples treated with 1000 to 4000 ppm of TBHQ antioxidant show BSFCs 7.9%, 8.53%, 9.34%, and 9.79% lower than that of diesel respectively. The variation of brake thermal efficiency (BTE) with load is shown in figure 2. BTE increases steadily with the load. BTEs follow a decreasing trend with increasing concentration of antioxidant in biodiesel. The addition of antioxidant decreases the heating value of biodiesel, which increases the mass flow rate of the engine resulting in higher BSFCs. The higher BSFC implies lower thermal efficiency (BTE). Moreover, poor atomization of pure biodiesel or any of the antioxidant-treated biodiesel due to higher density and viscosity prompts higher BSFCs thereby lowering their BTEs. Biodiesel test fuels treated with 1000 to 4000 ppm of TBHQ have BTE values 9%, 12%, 13% and 18% lower than that of diesel at full load condition. Though, there are variations of BTEs for different test fuels, the engine develops the same brake power at a particular load irrespective of the fuel used.

Table 1 — Physical & chemical properties of pomelo vegetable oil and biodiesel

S No	Properties	Pomelo oils	Pomelo oil biodiesel	Diesel
1	Density (kg/m^3)	917	822	834
2	Kinematic Viscosity (cSt)	32	1.92	2.6
3	Pour Point (^{0}C)	-6	-15	-16
4	Cloud Point (^{0}C)	-3	-4	-4
5	Calorific Value (MJ/kg)	39.06	27.1	53.54
6	Flash point (^{0}C)	-	151	66
7	Fire Pont (^{0}C)	-	200	-
8	FFA (%)	-	0.959	-
9	Acid Number	-	0.476	-

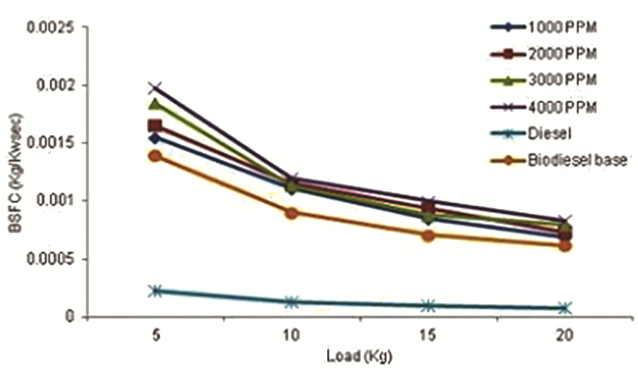

Fig. 1 — BSFC Vs Load

Emission performance

As TBHQ is added to biodiesel in various concentrations ranging from 1000 to 4000 PPM, it is important to know the carbon monoxide (CO) and carbon dioxide (CO_2) emission patterns during biodiesel utilization. Figure 3 demonstrates the CO and CO_2 emissions of the test fuels at full load. Unlike diesel, biodiesel with or without antioxidant has lower CO emission demonstrating complete combustion owing to their inherent oxygen content. However, the amount of TBHQ has no noteworthy impact on the CO characteristics compared to pure biodiesel. In the case of CO_2 emission too, TBHQ has no alarming impact. The percentage reductions in CO and CO_2

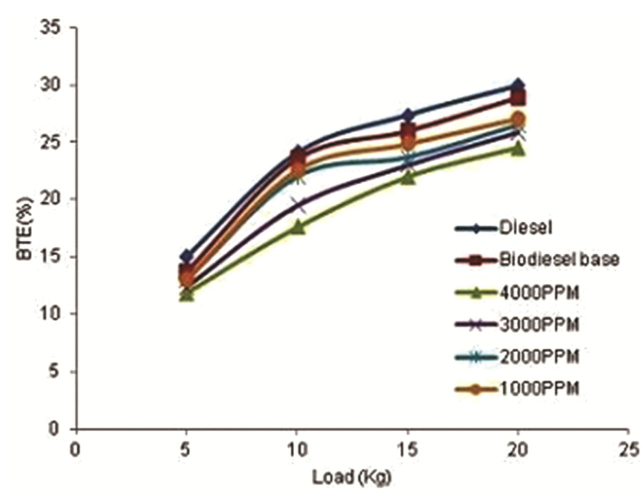

Fig. 2 — BTE Vs Load

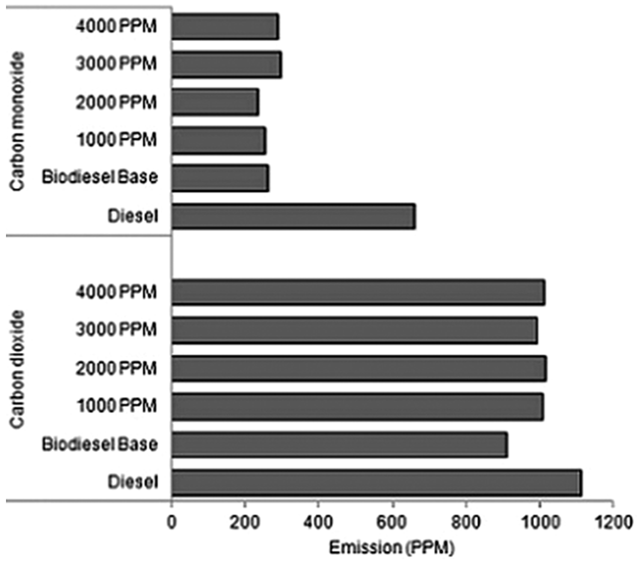

Fig. 3 — CO & CO_2 emission at full load

Table 2 — Percentage reductions in CO and CO_2 compared to the emission of diesel

Emission	0PPM	1000PPM	2000PPM	3000PPM	4000PPM
CO	60.00%	61.81%	64.39%	54.24%	56.06%
CO_2	18.0%	9.54%	8.55%	10.63%	9.09%

emissions occurred in the utilization of biodiesel with or without TBHQ are shown in table 2.

Conclusions

The present investigation assesses engine and emission performance of pomelo oil biodiesel with the varying concentration of TBHQ in a single cylinder four stroke diesel engine. The conclusions are,

1. Increase in BSFC has been observed with increasing concentration of TBHQ compared to diesel. As a result, the thermal efficiencies for biodiesel with or without TBHQ are lower than that of diesel.

2. The engine brake power is not at all impacted by TBHQ.

3. Considerable reductions in CO and CO_2 emissions have been observed for all the test fuels.

References

1 Fan R, Biodiesel production from fructus schisandra seed oil, *Indian J Biotechnol*, 16 (2017) 114-118.

2 Guraru VS, Optimization and characterization of biodiesel production from India originated bitter apricot kernel oil, *J Sci Ind Res*, 77 (2018) 345-348.

3 Du Plessis L.M. ,Stability studies on methyl and ethyl fatty acid esters of sunflower seed oil, *J Am Oil Chem Soc*, 62 (1985) 748–752.

4 Rashed M M, Stability of biodiesel, its improvement and the effect of antioxidant treated blends on engine performance, *RSC Adv*, 5 (2015) 36240-61

5 Middlemarch M & Schober S, The influence of antioxidants on the oxidation stability of biodiesel, *J Am Oil Chem Soc*, 80 (2003) 817–823.

6 Dunn, R. O., Effect of antioxidants on the oxidative stability of methyl soy ate, *Fuel Process. Technol*, 86 (2005) 1071 - 1085.

7 Gui M, Feasibility of Edible Oil vs. non-Edible Oil vs. Waste Edible Oil as Biodiesel Feedstock, *Energy*, 33 (2008) 1646-1653.

8 Kivevele T, Impact of antioxidant additives on the oxidation stability of biodiesel produced from Croton Megalocarpus oil, *Fuel Process. Technol, 92* (2011) 1244-1248.

9 Yang Z, Hollebone, B P, Wang, Z, Yang C, and Landriault M, Factors affecting oxidation stability of commercially available biodiesel products, *Fuel Process. Technol*, 106 (2013) 366–375.

10 Obadiah R, Study on the effect of antioxidants on the long-term storage and oxidation stability of Pongamia Pinnata (L.) biodiesel, *Fuel Process. Technol*, 99 (2012) 56-63.

11 Ryu K, The characteristics of performance and exhaust emissions of a diesel engine using a biodiesel with antioxidants, *Biores Technol*, 101 (2010) 75-82.