Experimental Analysis of Hevea Brasiliensis Methyl Ester Diesel Blend with Antioxidant Additive in a Di-diesel Engine

A. A. Muhammad Irfan, Sivanandi Periyasamy, and A. Gurusamy

Abstract To replacing diesel fuel non-edible feedstock is a probable resource for the alternative fuel creation with taken into account of ecological and food versus fuel demand. Biodiesel is a capable replacement to diesel fuel, due to renewable, non-hazardous, transportable, widely existing, recyclable, ecological, and free from sulfur and aromatic matter. The experimental investigation was carried out, to investigate the response of Hevea brasiliensis methyl ester diesel blend with antioxidant additive in a di-diesel engine. The performance and emission characteristics were determined for the diesel engine powered with Hevea brasiliensis biodiesel blend. With an aid of ASTM standards, tert-butylhydroquinone (TBHQ) antioxidant added in biodiesel blend. The performance and emission distinctiveness were resolute for antioxidant additive added blend. The outcome of antioxidant additive on the performance and emission of diesel engine were analyzed and concluded with base fuel. The addition of antioxidant increased 8.9% average brake thermal efficiency, increased 4.98% average mechanical efficiency, and reduced 8.9% average brake specific fuel consumption. The addition of antioxidant reduced oxides of nitrogen (NO_x) emission, but increased carbon monoxide (CO), carbon dioxide (CO_2), and hydrocarbon (HC) emissions compared to Hevea brasiliensis biodiesel blend.

Keywords Hevea brasiliensis · Transesterified · Antioxidant · Tert-butylhydroquinone · Brake specific fuel consumption · Brake thermal efficiency · Emission characteristics

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Nomenclature

HBME	Hevea brasiliensis methyl ester
TBHQ	Tert-butylhydroquinone
D80 + HBME20	Diesel 80% + Hevea brasiliensis methyl ester 20%
D70 + HBME20 + TBHQ10	Diesel 70% + Hevea brasiliensis methyl ester 20% + tert-butylhydroquinone 10%
B20	Diesel 80% + biodiesel 20%
BSFC	Brake-specific fuel consumption
BTE	Brake thermal efficiency
ME	Mechanical efficiency
CV	Calorific value of fuel
NOx	Oxides of nitrogen
HC	Hydro carbon
CO	Carbon monoxide
CO_2	Carbon dioxide

1 Introduction

IC engine responded good for biodiesel on a place of diesel. Reduction of emissions in diesel engines is a current researcher's agenda by introducing biodiesel. Researchers compared the diesel with various feedstock biodiesels to find out better alternative biodiesel. Hevea brasiliensis is the botanical name rubber seed.

Atabani et al. [1] identified the biggest Hevea brasiliensis producers are Thailand, Indonesia, Malaysia, India, China around the earth with 35%, 23%, 12%, 9%, 7% shares, respectively. Takase et al. [2] recognized the Hevea brasiliensis oil taken in a calendar year is 70–500 kg/ha and oil collected from seeds nearly 50–60% and 40–50% from its kernel. Ramadhas et al. [3] documented Hevea brasiliensis requiring acid esterification and transesterification due to a high acid value of Hevea brasiliensis.

Ramadhas et al. [4] utilized the biodiesel of Hevea brasiliensis in diesel engine and conducted the performance and emissions test. Their conclusion showed thermal efficiency of biodiesel blends are higher while lower concentrations. Still, NO_x emission is also projected to increases with increase in biodiesel blends.

Erol Ileri et al. [5] concluded that decreasing NO_x emissions and improving oxidation stability by using antioxidants additives in biodiesel blends. Erol Ileri et al. [6] concluded that reduction and increased of NO_x and CO, respectively, by using antioxidants in biodiesel blends. Rashid et al. [7] reported by addition the antioxidant with Calophyllum inophyllum methyl ester (B20), BTE and BP improved while decreasing BSFC. At the same time, antioxidants reduced NO_x, growth of HC and CO for all biodiesel blends. For this reason, aromatic amine antioxidants can be used with B20 blends, in compression, ignition engine exclusive of any engine alterations.

Jain et al. [8] compared the efficiency of eight artificial antioxidants in dissimilar biodiesels and they concluded that only three antioxidants considerably improved the stability of biodiesel in the increasing order of propyl gallate, pyrogallol, and TBHQ. David et al. [9] predicted the result, in induction time of methylic biodiesel later than add-ons of increasing concentrations of TBHQ. Oxidation stability is directly proportional to the concentrations of TBHQ. Palash et al., 2014 [10] concluded that NO_x emissions reduced notably by using antioxidant additive with a small degradation in engine power and BSFC as well as CO and HC emissions. Rashedul et al. [11] evaluated that the performance and emission characteristics as well as properties of biodiesel were improved notably by using additives.

2 Materials and Methods

2.1 Experimental Setup

The investigational setup of single-cylinder four-stroke engine as shown in Fig. 1 is loading by eddy current dynamometer with direct injection. Assessment of performance and emission characteristics of required samples are taken by using this engine with water cooling concept. The engine specification of this engine was mentioned in the below Table 1.

Fig. 1 Photograph of experimental setup

Table 1 Engine specification

Manufacturer	Kirloskar oil Engine Ltd., India
Method of injection	Direct injection diesel engine
Number of cylinders	Single cylinder
Number of strokes	Four stroke
Cooling type	Water cooling
Engine speed	1500 rpm
Brake power	3.5 kW @ 1500 rpm
Bore diameter	80 mm
Stroke length	110 mm
Type of loading	Eddy current dynamometer
Starting method	Manual cranking
Compression ratio	16.5:1
Orifice diameter	0.02 m
Dynamometer Arm length	0.185

2.2 *Preparation of Biodiesel*

Hevea brasiliensis methyl ester was collected only after two esterification process. Acid esterification is the first stage, carried out at 650 rpm, 55–57 °C for 90 min with 0.7% of weight of H_2SO_4, and oil to methyl alcohol about 2:1 volume ratio in the magnetic stirrer. The second stage is performed at 650 rpm, 60 °C for 60 min with 0.5 wt% NaOH pellets with volume ratio of 10:1 acid esterified oil to methanol in the magnetic stirrer. The Hevea brasiliensis methyl ester was derived from the above process. But it contains impurities as well as glycerin. Outcome of pure methyl esters only happens after several washing processes by distilled water.

2.3 *Properties of Hevea Brasiliensis Methyl Ester and TBHQ*

The major fuel properties were determined as per the ASTM standards and evaluated values are given in Table 2.

Table 2 Properties of sample fuel

Property parameters	Unit	Diesel	HBME	TBHQ
Density	g/cc	0.833	0.886	0.905
Flash point	°C	68	167	171
Fire point	°C	63	181	189
Kinematic viscosity	cSt	3.22	5.78	5.98

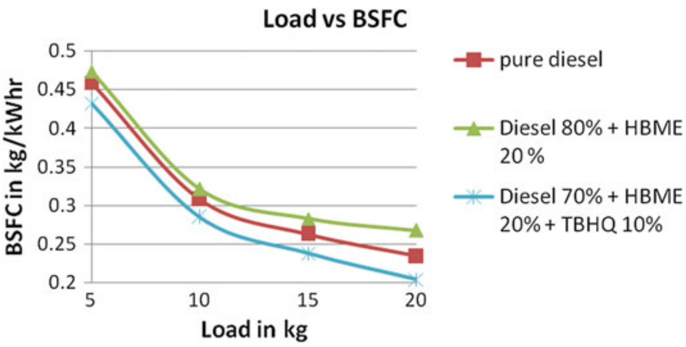

Fig. 2 Brake-specific fuel consumption

3 Results and Discussions

3.1 Performance Characteristics

Performance of sample biodiesel blends was taken with and without TBHQ. The engine was maintained at stable speed for all loads of 1500 rpm. While taking the performance test, 10 cc fuel utilization time taken was followed throughout the various blends.

3.1.1 Brake Specific Fuel Consumption

Figure 2 shows that load versus BSFC curve for different biodiesel blends. The BSFC for D70 + HBME20 + TBHQ10 blend was found to be lower. The BSFC for D80 + CHBME20 is higher than all additive added blend and pure diesel. BSFC for HBME20 blend was slightly increased due to less heating content of Hevea brasiliensis biodiesel. Due to the higher power output, BSFC was decreased on the addition of TBHQ.

3.1.2 Brake Thermal Efficiency

The base fuel has lesser efficiency than blended fuels. The effect of various blends on BTE was shown in Fig. 3. It was clearly indicated that the addition of TBHQ shows highest BTE at all working conditions. Also at higher loads, the increase in BTE was observed for all blends. Reason of this happens because of, the fuel viscosity decreases for the blends, made finer fuel particles which in turn makes the atomization process easier and efficient. This aids to the huge improvement of combustion by mixing of fuel with oxidizer.

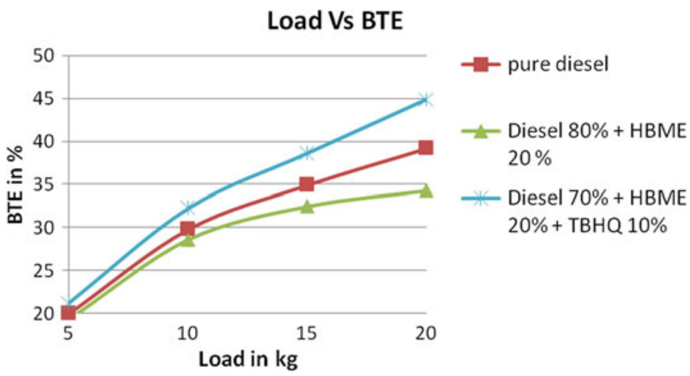

Fig. 3 Brake thermal efficiency

3.1.3 Mechanical Efficiency

From experiments, it was observed that increases in mechanical efficiency of the various while load increases as shown in Fig. 4. It was due to that the fuel viscosity decreases, made finer fuel particles which in turn makes the atomization process easier and efficient. This helps to the improvement of combustion by mixing of fuel with oxidizer.

3.2 Emission Characteristics

AVL gas analyzer was used to analyzing the emission characteristics for various biodiesel blends at different loading condition. HC, NO_x, CO, and CO_2, emissions are measured by using this analyzer.

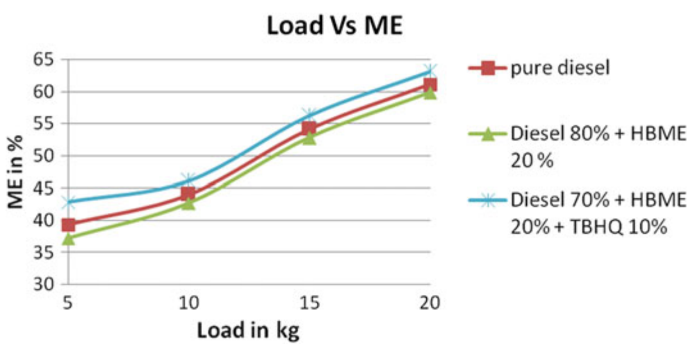

Fig. 4 Mechanical efficiency

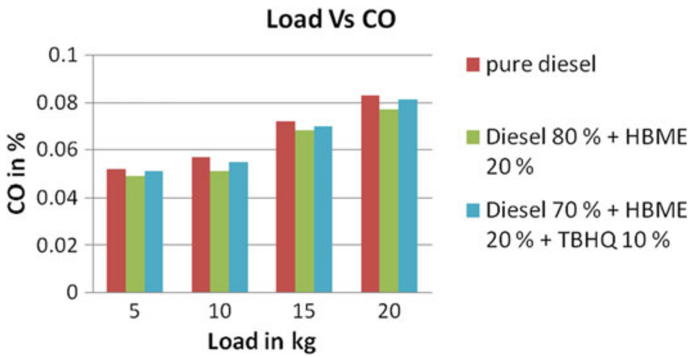

Fig. 5 CO emissions

3.2.1 CO Emission

As shown in Fig. 5, biodiesel addition will reduce the CO formation. Due to the lower participation of fuel at lesser loads, less CO emission was noted. Here, CO directly proportional to the engine loads. Results obtained from various biodiesel blends indicate that reduced CO emission by reason of containing high oxygen and highest cetane number of the Hevea brasiliensis blends. Enhancement in fuel borne oxygen gives complete combustion range of CO, thus lower the CO emission considerably. TBHQ mixed with HBME20 gives highest unburnt CO emission compared to HBME20 blend. However, the level was within emission standards.

3.2.2 CO_2 Emission

As shown in Fig. 6, the biodiesel concentration level will minimize the CO_2 emission. Here, CO_2 directly proportional to the engine loads. TBHQ blend shows reduced CO_2 emission, but it slightly higher than HBME20. This is because of the lower operating temperature due to its high latent heat of vaporization.

3.2.3 HC Emission

HC emission was slightly decreased with blend addition which was shown in Fig. 7. Due to the lower participation of fuel at lesser loads, less HC emission was noted. It will slightly increase with engine load increases. Results obtained from various biodiesel blends indicate that reduced HC emission by reason of containing high oxygen and highest cetane number of the Hevea brasiliensis blends. Enhancement in fuel borne oxygen gives complete combustion range of HC, thus lower the HC

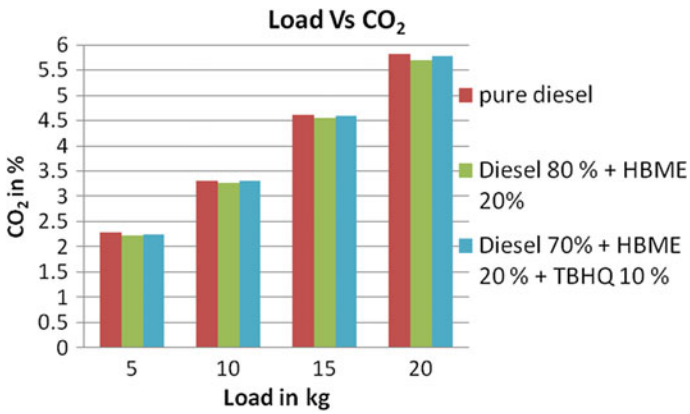

Fig. 6 CO_2 emission

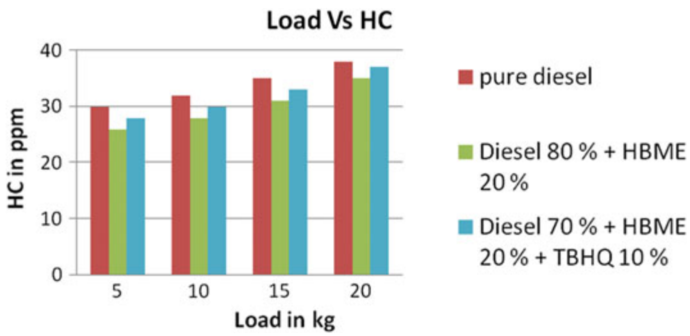

Fig. 7 Hydrocarbon emission

emission considerably. Unburnt HC emission was increased because of Accumulation of TBHQ to HBME20 compared to HBME20 blend. However, the level was within emission standards.

3.2.4 NO_x Emission

Load affects the NO_x emission with linear manner as shown in Fig. 8. Shorter ignition delay and oxygenated fuel produce the convenient combustion. It affects NO_x emission slightly above the diesel. The positive result shows on the addition of TBHQ to HBME20 to controlling the NO_x. Reduction of NOx emission occurs by phenolic hydroxyl groups present in the TBHQ.

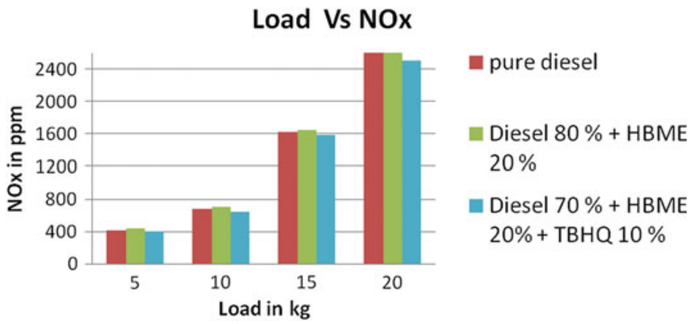

Fig. 8 NOx emission

4 Conclusion

The experimental analysis clearly indicates the following conclusions; the biodiesel prepared from Hevea brasiliensis oil shows the feasible to be a feedstock for biodiesel production. The investigation in terms of performance and emission was taken at D80 + HBME20 blend with and without the presence of tert-butylhydroquinone (TBHQ) antioxidant additive in direct injection four-stroke single-cylinder diesel engine. TBHQ blend gives highest BTE at all loading conditions. The increase in average BTE was 8.9% instead of diesel. Average BSFC of D80 + HBME20 increased by 6.67% instead of diesel. There was 8.9% reduction in average BSFC for D70 + HBME20 + TBHQ10 blend compared to diesel. BSFC increases for D80 + HBME20 blend was due to lower heating content of Hevea brasiliensis biodiesel. Average HC and CO emissions of D80 + HBME20 decreased by 11.29% and 7.27%, respectively, compared to diesel. Reduction in emission of HC and CO was due to the collective end product of its high oxygen content and superior cetane number. Average NO_x emission of D80 + HBME20 increased by 2.67%, while average NO_x emission of D70 + HBME20 + TBHQ10 reduced by 4.07% in comparison with diesel. ASTM D6751 biodiesel standard was satisfied with HBME's fuel properties. Hence, HBME can be recommended instead of diesel fuel. It deals with the universal concerns of energy disaster and ecological deprivation problems.

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