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Assessment of emission and performance characteristics of WCO based biodiesel and n-butanol blends in CI engine

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ABSTRACT: Increased concerns of depleting petroleum fuel resources and increasing environmental issues have led to the increased usage of bio-fuels, especially biodiesel. Biodiesel is a renewable, biodegradable and non-toxic alternative to diesel. It can be used without any modification in the diesel engine. The use of waste cooking oil (WCO) as biodiesel feedstock offers a triple-facet solution (economic, environmental and waste management) in developing countries like India as well. In current study, waste cooking oil was trans-esterified to produce biodiesel using molar ratio 6:1. Methanol was used as alcohol substitute. Performance analysis was done by keeping speed constant at 1500 rpm and varying loads on a stationary diesel engine. Also, n-butanol was used as oxygenated additive. The experiments were performed by using various blends of diesel and biodiesel & diesel-biodiesel and n-butanol. 20%, 40% and 60% biodiesel was first blended with diesel and 10% and 20% n-buatnol were also blended later on. Performance and emission characteristics were checked and compared with diesel base. Results showed that HC, CO, CO_2 and smoke emissions were reduced significantly by 15-25%, 10-25%, 10-30% and 20-28% respectively whereas a slight increase in NOx emissions was observed. However addition of n-butanol decreased the NOx emissions by 1-10%. Performance characteristics BHP, BTE, BSFC, BSEC were also considered and compared. Results indicated that B20 and nB10 blends were optimum and most economic to be used in any diesel engine.

Keywords: Waste Cooking Oil (WCO), n-butanol, trans-esterification, emissions.

I. INTRODUCTION

Alternative resources for petrol and diesel fuels are getting attention as entire world is facing the problem of depletion of petroleum reserves and increased environmental pollutants [1]. With the increasingly emission standards and lesser energy, it has become important to develop new internal combustion engines having low emissions and high fuel efficiency [2]. In this regard, biodiesel can be a dominant diesel substitute. It is produced from renewable sources like plants and vegetable oils and moreover it reduces environmental concerns [3].

Waste cooking oils are degraded vegetable oils which may possess foreign material. These can be proved to be inexhaustible source of energy and power. The difference in properties of used and unused vegetable oil is not much and it can be overcome by simple heating and subsequent filtration. These can be great feedstock for biodiesel production.

Also, it is economical and solves the problem of waste cooking oil disposal. Biodiesel production cuts exhaust emissions as well. Biodiesel can be defined as "Biodiesel is a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100, and meeting the requirements of ASTM D 6751". Biodiesel only contains about 10% oxygen by weight which leads to reduction in emissions due to incomplete combustions [4,5].

Literature studies reveal that vegetable oils are 10-20 times more viscous than the petroleum fuel; therefore directly using vegetable oils as a fuel can cause engine problems like injector fouling and particle agglomeration [6]. So, heating the oil becomes necessary before trans-esterification. Also, oxygenated fuel program was started in 1990 to avoid the problem of cold flow properties of oils especially in winter season.

The program was mainly to reduce carbon mono oxide emissions from vehicles. Previously ethanol was used as oxygenated fuel but now a days several other fuels are also in trend. In trends of oxygenated fuels, *n*-Butanol has been recently regarded as a more viable transportation biofuel than ethanol. It is less hygroscopic and evaporative than ethanol [7]. More oxygen content in oxygenated fuels is helpful in reducing PM emissions. >30% oxygen content results in no PM emissions from diesel engines [8]. Also, a study by Miyamoto *et al* (1998) revealed that biodiesel is much biodegradable than low sulfur diesel fuel and blending of biodiesel to diesel fuels makes fuel more biodegradable and more environmentally attractive [9].

Blending oils with oxygenated fuels improves fuel properties [10]. There are several studies on the performance analysis of blending biodiesel with diesel. In a similar study, S.K. Mahla *et al.* (2012) examined the properties, performance and emission of B15, B20 and B30 blends of linseed methyl esters and compared it to diesel[11]. He observed B20 to be most optimum in terms of better performance and reduced emissions. B15 and B30 blend were also reasonably efficient having lower smoke, CO and HC emissions. Also, a study by Jindal *et al* (2014) on Waste Cooking Oils had similar results [12]. Current study indicates that efficiency of biodiesel raised by 13% by adding n-butanol. B20 was the optimum blend and addition of 10% n-butanol proved even more efficient fuel.

II. MATERIALS AND METHODOLOGY

Waste cooking oil was used as feedstock for biodiesel production. It was taken from the Girls hostel mess from Thapar University Patiala. 1% KOH by weight was used and methanol (99.5%) was preferred due to its low cost. Less than 1% fatty acid content led to the use of alkali catalyst. Single stage alkaline trans-esterification reaction was done using 6:1 molar ratio. Trans-esterification is a reaction of oils and alcohols to form esters.

Blending was done by mixing different ratios of diesel, biodiesel and n-butanol. Total 5 blends were made-B20, B40, B60, nB10 and nB20. The emission and performance of these blends was checked.

Engine set-up

A 4-stroke engine of power 3.73 kW, one cylinder was used at constant speed 1500 rpm with following specifications as mentioned in Table 1.

Table 1: Specifications of Engine.

Parameters	Details
Manufacturer	Kirloskar Oil Engines Limited India
Dynamometer	Eddy Current
Bore, mm	80
Stroke, mm	110
Displacement Volume, cc	252.9
Compression Ratio	16.5:1
Cooling System	Air Cooled
Horse Power	6.5
Injection Pressure	200 kg/cm^2
Voltage, V	240
Current, Ampere	17.5

III. RESULTS AND DISCUSSION

A. Emission Characteristics

The decrease in HC emission occurs with increase in biodiesel blend. B60 showed 55-65% at lower loads and 40-50% at higher loads while B20 showed 15-25% decrease in HC emission at all loads. Butanol blends showed 20-45% decrease at all loads.

It was observed that with increase in load the CO emissions increased. This is due to the injection of rich air fuel mixture which led to incomplete combustion of fuel. But with further increase in blend content the emissions were observed to be decreased. This may be due to the higher oxygen content which leads to complete combustion. B40 showed 8-50% decrease and B60 showed 10-25% decrease. The CO emissions were decreased with increase in n-butanol concentration which lowers the delay period and improves the combustion. Butanol addition lowered the emissions by 3-15%.

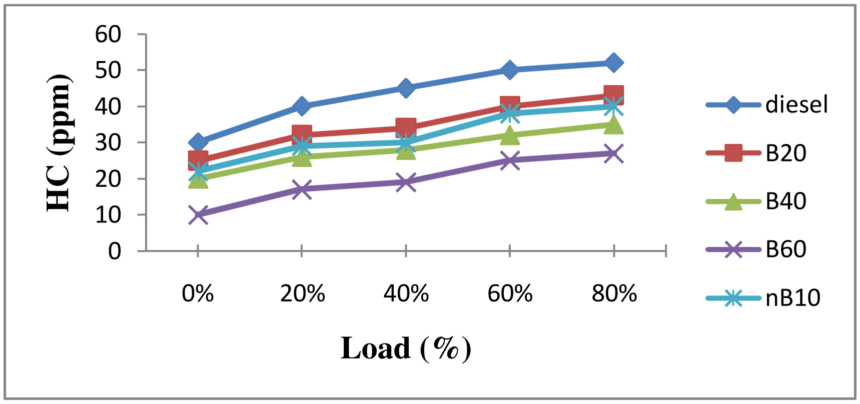

Fig. 1. Hydrocarbon emissions variation with load.

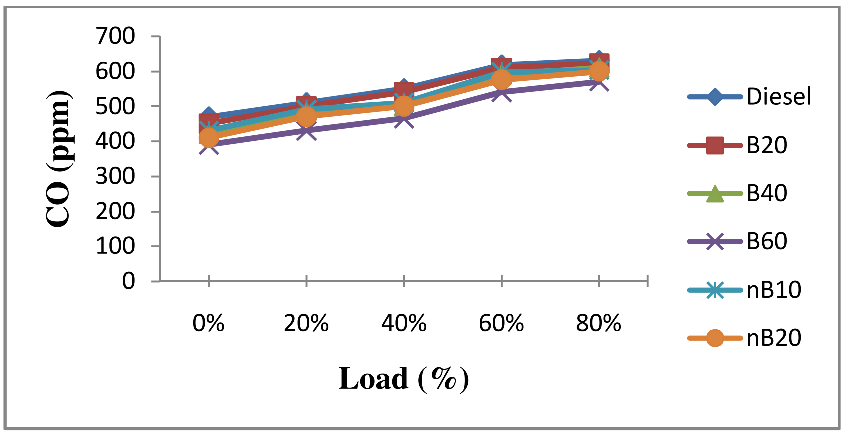

Fig. 2. Carbon mono-oxide emissions variation with load.

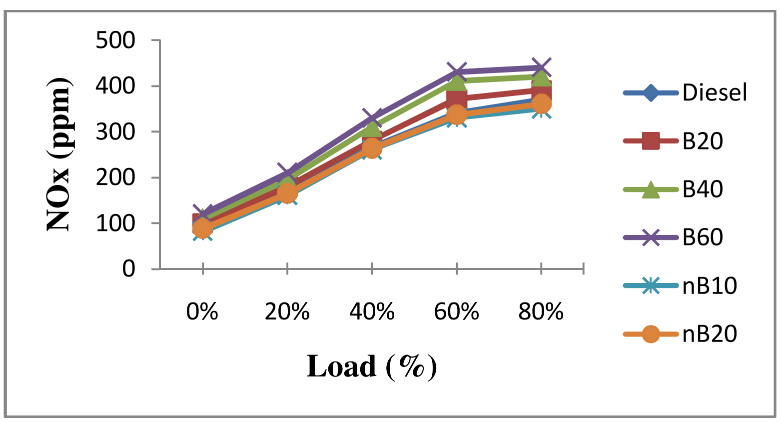

Fig. 3. NOx emissions variation with load.

NOx emissions increased with WCO methyl ester at the pace of 5-25% whereas addition of butanol decreased the NOx emissions by 1-10%. It was observed that with increase in load the CO_2 emissions increases due to better combustion at high loads. The CO_2 emissions with diesel were highest.

As the blend content increased, the CO_2 emissions were decreased. The CO_2 emissions were observed to be decreased significantly with the increase in butanol content due to the good oxygen content and lower ignition delay that led to better combustion.

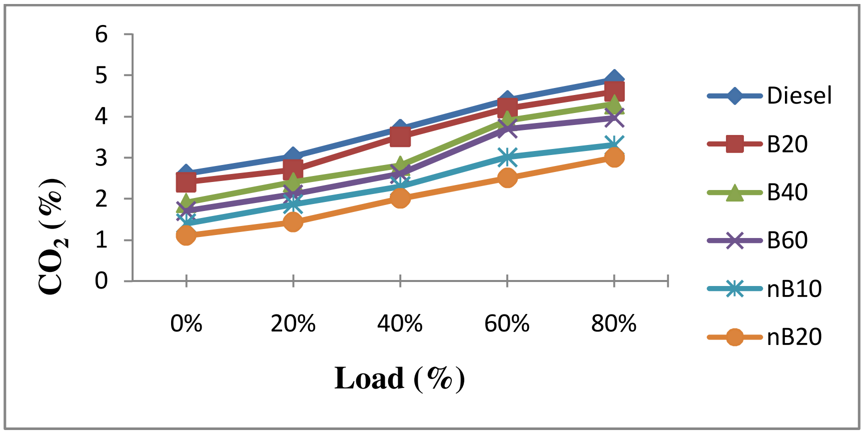

Fig. 4. Carbon dioxide emissions variation with load.

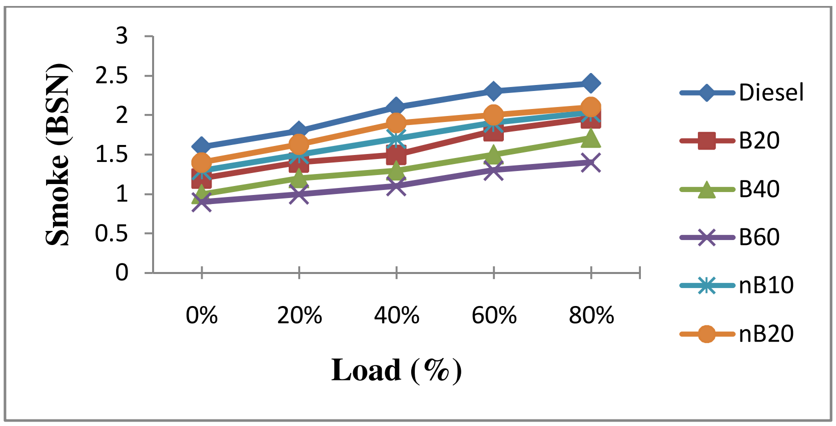

Fig. 5. Smoke variation with load.

B20 showed 20-28% decrease in smoke where as B40 and B60 showed 34-50% decrease in smoke as compared to diesel. Butanol blends showed 10-25% decrease in smoke as compared to diesel fuel.

B. Engine Performance Analysis

Brake Horse Power (BHP) increases with load in every case. BHP varies with current as voltage is almost constant. BHP is zero at no load as there is no current flow. B20 showed 8% increase while B60 showed higher increase level (15-20%). n-Butanol also had similar variations as B20.

Brake Fuel specific Consumption (BSFC) varies inversely to load. BSFC decrement was more at higher loads. B20 showed 5% difference at lower loads and of 2% at higher loads. Addition of n-butanol proved to be great advantage. BSFC was 25% at lower loads and 15% at higher loads in n-butanol blends.

Brake Thermal Efficiency (BTE) changes directly with BHP and inversely with calorific value. B20 proved 13.2% more efficient as compared to diesel at lower loads and 7.3% more at higher loads. Other blends were also more efficient s compared to diesel and range varied from 2-7%.

Brake Specific Energy Consumption (BSEC) is useful to compare the fuels of different calorific values. The BSEC varies inversely with load for all fuel blends. Higher biodiesel blends and butanol had higher BSEC compared to diesel at all loads. This is mainly due to the slightly lower calorific value. In Figure, B20 and nB10 blends showed a decrease of about 0.1-9% in BSEC at all load as compared to diesel. B40 and B60 showed increase of about 4-15% in BSEC at all loads.

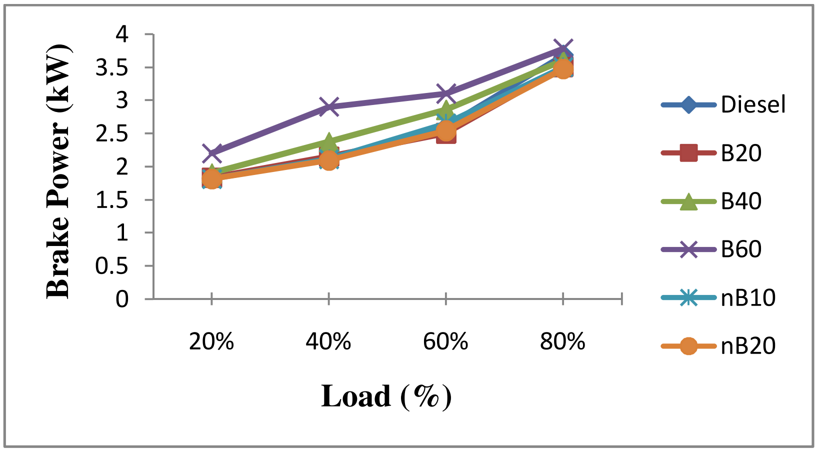

Fig. 6. Brake power variation with load.

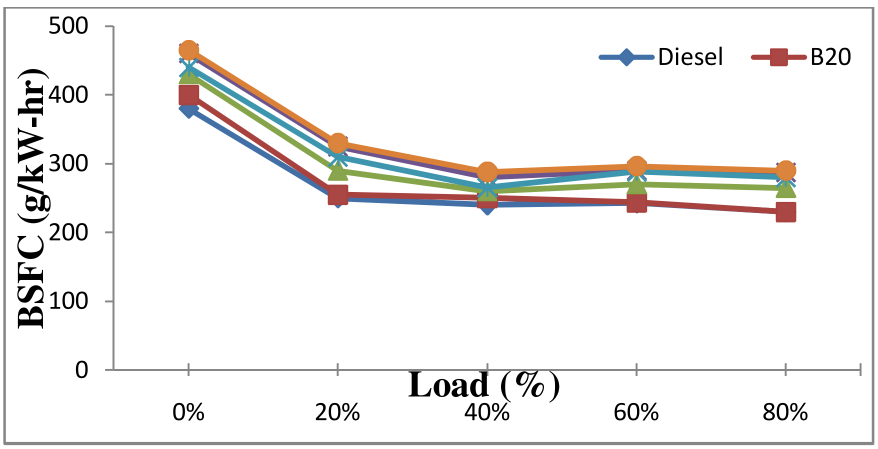

Fig. 7. BSFC variation with load.

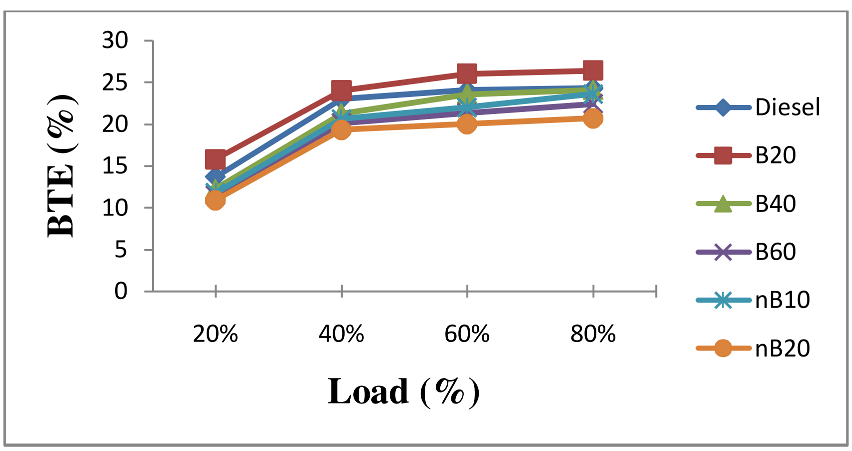

Fig. 8. BTE variation with load.

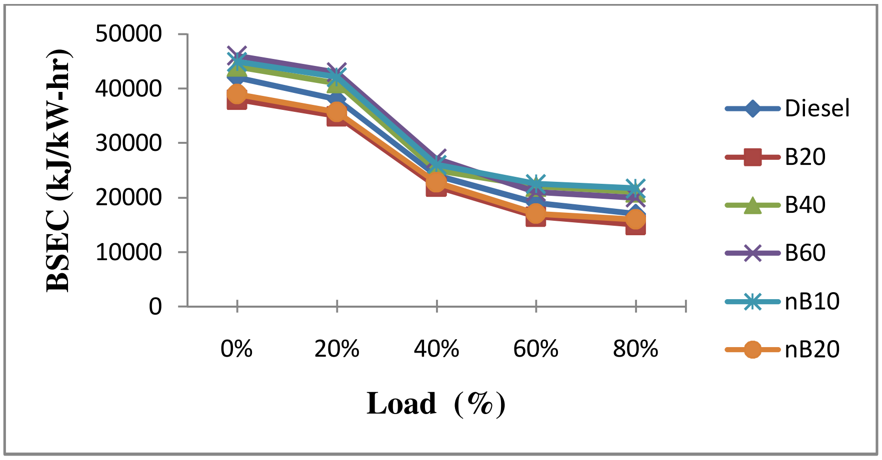

Fig. 9. BSEC variation with load.

CONCLUSIONS

(i) The lower biodiesel blends can be used in diesel engine without any engine modifications. However, need to change fuel filter remains after regular intervals of time.

(ii) B20 proved to be most optimum blend. nB10 was also good at all load conditions. More content of oxygen helped in complete combustion and decreased emissions.

(iii) The properties and performance of bio-diesel-n-butanol-diesel blends resemble with the conventional diesel on CI engines. However, the emissions were lower in biodiesel blends which indicate the regular use of biodiesel as transport fuel. The economic aspects of biodiesel needs to be considered.

REFERENCES

[1]. Fukuda H, Kondo A, Noda H. Biodiesel fuel production by transesterification of oils. *Journal of bioscience and bioengineering*. 2001 Dec 31; **92**(5): 405-16.

[2]. Lei J, Bi Y, Shen L. Performance and emission characteristics of diesel engine fueled with ethanol-diesel blends in different altitude regions. *BioMed Research International*. 2010 Dec 27; 2011.

[3]. Pramanik P, Das P, Kim PJ. Preparation of biofuel from argemone seed oil by an alternative cost-effective technique. Fuel. 2012 Jan 31; **91**(1): 81-6.

[4]. McCormick RL, Williams A, Ireland J, Hayes RR. Effects of biodiesel blends on vehicle emissions: fiscal year 2006 annual operating plan milestone 10.4. National Renewable Energy Laboratory (NREL), Golden, CO.; 2006 Oct 1.

[5]. Pehan S, Jerman MS, Kegl M, Kegl B. Biodiesel influence on tribology characteristics of a diesel engine. *Fuel*. 2009 Jun 30; **88**(6):970-9.

[6]. Knothe G, Sharp CA, Ryan TW. Exhaust emissions of biodiesel, petrodiesel, neat methyl esters, and alkanes in a new technology engine. *Energy & Fuels*. 2006 Jan 18; **20**(1):403-8.

[7]. Ezeji TC, Qureshi N, Blaschek HP. Bioproduction of butanol from biomass: from genes to bioreactors. Current opinion in biotechnology. 2007 Jun 30; **18**(3): 220-7.

[8]. Miyamoto N, Ogawa H, Nurun NM, Obata K, Arima T. Smokeless, low NOx, high thermal efficiency, and low noise diesel combustion with oxygenated agents as main fuel. SAE technical paper; 1998 Feb 23.

[9]. Zhang Y, Dube MA, McLean DD, Kates M. Biodiesel production from waste cooking oil via two-step catalyzed process. *Energ. Convers. Manage*. 2003; **48**: 184-8.

[10]. Boehman AL, Morris D, Szybist J, Esen E. The impact of the bulk modulus of diesel fuels on fuel injection timing. *Energy & Fuels*. 2004 Nov 17; **18**(6): 1877-82.

[11]. Mahla SK, Birdi A. Performance and Emission Characteristics of Different Blends of Linseed Methyl Ester on Diesel Engine. 2012.

[12]. Jindal M, Rosha P, Mahla SK, Dhir A. Experimental investigation of performance and emissions characteristics of waste cooking oil biodiesel and n-butanol blends in a compression ignition engine. *RSC Advances*. 2015; **5**(43): 33863-8.