NO_x and HC Emissions Reduction from a Diesel Engine Fuelled with Various Biodiesel Blends- A Review

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ABSTRACT— ***Biodiesel is a clean, renewable and environmentally friendly fuel, derived from various feedstock's like: edible and non-edible oils. Moving towards renewable energy sources, to overcome the problems of rising fossil fuel price, increasing dependency on foreign energy sources, and environmental concerns. We use the biodiesel blends as B_{20} (20% biodiesel and 80% diesel) because B_{20} blend shows as comparative properties as diesel .In this review work we study the effect of various biodiesel blends like: Palm biodiesel blend (PB_{20}), Calophyllum inophyllum biodiesel blend (CIB_{20}), Jatropha biodiesel blend (JB_{20}), Karanja biodiesel blend (KB_{20}), Microalgae biodiesel blend (MGB_{20}), Mahua biodiesel blend (MB_{20}) and diesel on diesel engine performance characteristics in term of brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE), emissions characteristics as NO_x, CO, HC emission and smoke intensity, compared to diesel. We can concluded that MGB_{20} blend having the highest BTE and lower BSFC of among all blends. Diesel produce minimum NO_x emission compared to biodiesel blends. NO_x emission is reduce by 13.33, 33.33, 26.67, 43.33 and 50% for MGB_{20} when compared to CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} blends and increase by 15.38% when compared to diesel. So MGB_{20} biodiesel blend can be used in diesel engine without any modifications in diesel engine if NO_x and HC emissions are the main criteria.***

Keywords— Biodiesel, Renewable energy, Diesel engine, NO_x emission, Microalgae biodiesel blend (MGB_{20}).

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1. INTRODUCTION

The consumption of energy sources is increase because the use of fossil fuels in transportation, electric generators etc. [1]. Price of fossil fuels such as coal, gas and petroleum products are increasing which are cause to discover an alternative fuel in place of fossil fuels [2]. It has been investigated that the human health threats are related with exposure to diesel emissions [3]. Biodiesel are derived from edible oil are peanut, soybean, sunflower, rice bran, palm, coconut oil etc; and non-edible oil sources as Jatropha curcas, Pongamia (karanja), Madhuca indica (Mahua), Cotton seed, tobacco and Calophyllum inophyllum oils. Biodiesel is used in diesel engine as an alternative fuel of diesel, which is produced from natural sources. Biodiesel is an eco-friendly, oxygenated, nontoxic, sulfur-free and renewable, used in diesel engines either in pure form or blends with diesel without any engine modification [4]. The use of biodiesel fuels in diesel engines having environmental and economic advantages such as reduction in emissions and improved energy security. By using the biodiesel in diesel can reduce the harmful emissions like: Carbon monoxide (CO), Carbon oxide (CO_2), Hydrocarbon (HC) and particular matter (PM), expect that NO_x when compared to diesel [5]. Biodiesel increase the NO_x emission from diesel engine because it has higher oxygen content than diesel which improve the combustion process which increase the flame temperature of diesel engine causes to increase the NO_x emission. Fuel injection systems play an important role for reducing the emissions and improving fuel economy. Injection timing, duration and pressure are the major parameters which affect the engine performance and emissions characteristics [6]. It is reported that in a four-cylinder diesel engine at full load and different engine speeds using various biodiesel blends the power is almost same as diesel for B_{20} biodiesel blend and reduce with the increasing the blend ratio. This paper reported that BSFC is higher and reduce the BTE for MB_{20}, MGB_{20}, PB_{20}, JB_{20}, KB_{20} and CIB_{20} when compared to diesel. Palash et.al. [7] concluded that JB_{20} blends reduce the HC emission by 48% and increase in NO_x emission by 11.32% when compared to diesel because higher kinematic viscosity and density increase the injection pressure that higher fuel is required which improve the combustion results higher combustion temperature. Islam et.al. [8] found that NO_x emission increase by 5% and HC emission reduce by 40% for MGB_{20} compared to diesel at higher brake mean effective pressure (BMEP). Rashed et.al. [9] concluded that PB_{20} blend increase the NO_x emission by 6.91% and reduce the HC emission 30.26% when compared to diesel, Higher NO_x and Low HC emission for biodiesel blend can be explained by the higher oxygen contents and higher cetane number of biodiesel blend. Gopal et.al. [10] concluded that KB_{20} blend reduce the HC emission by 25% and increase the NO_x emission by about 7.70% when compared to diesel. The high combustion temperature and higher oxygen content in biodiesel blend than diesel, are causes for higher NO_x emissions.

From the above literature it is clear that by using the different biodiesel blends in diesel engine can reduce the HC emission and increase the NO_x emission as compared to diesel because biodiesel blends having higher oxygen content which improve the combustion causes to higher combustion temperature which results the increase the NO_x emission and reduce the HC emission. In this review paper we investigate the diesel engine performance and emissions characteristics by using the various biodiesel blends and focus on the NO_x emission because it contain the greenhouse gas which are harmful for human as well as environmental.

2. MATERIAL AND METHODS

2.1 Production of biodiesel

Biodiesel is clean, renewable and environmentally friendly fuel which are derived from edible and non-edible oils by the transesterification process, are shown in **Figure 1**. In this reaction mainly methanol has been used as alcohol and H_2SO_4 and NaOH are used as acid and base catalyst because their lower cost and easily availability [11]. The reaction is completed is two parts one is esterification when crude oil is mixed with methanol (90:10 v/v) and acid catalyst H_2SO_4 (1% v/v) is used for completion the process, after that esterification process the glycerol are removed which are present in crude biodiesel and it is mixed with methanol and base catalyst NaOH for invalidating the acid effect present in crude biodiesel this process is called as transesterification process. After the transesterification process the mixture are poured is separating funnel for 10-12 hours or overnight for settle down the glycerol, after removing the glycerol, the crude biodiesel is washed with hot water for 4-5 times. The washed biodiesel is heated about 100-120 ^oC for removing the water particle which are left during the washing process and it is flittered with flitter paper for purification of the biodiesel . If we used as 100 ml. of crude oil and 10 ml. of methanol than after the transesterification process we get the 100 ml. biodiesel and 10 ml. glycerol.

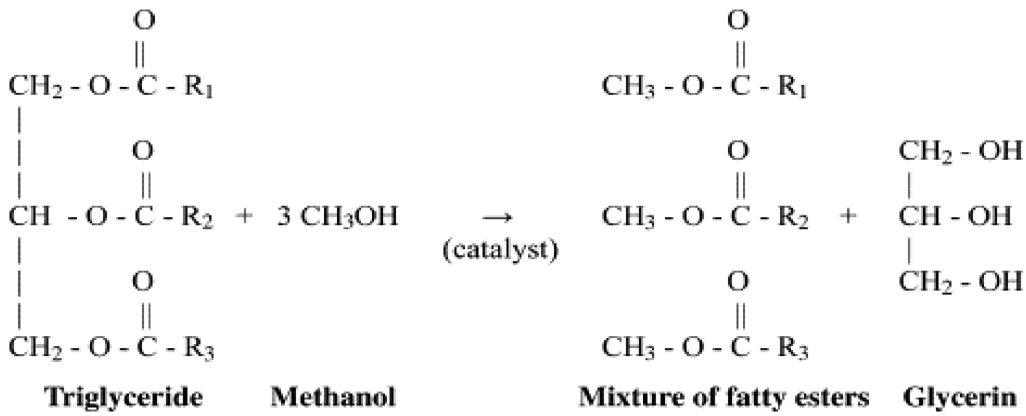

Figure 1: Transesterification process of biodiesel production [11]

2.2 Preparation of biodiesel blends

The biodiesel blends are prepared with diesel as contain 80% diesel and 20% biodiesel as nominated as B_{20} because it shows the comparable properties as diesel fuel like: calorific value, density, kinematic viscosity and flash point etc [12]. The biodiesel blends are prepared for Microalgae, mahua, Karanja, Jatropha, Palm and calophyllum inophyllum biodiesel [13]. MGB_{20} are shown the comparable fuel properties as diesel and better than other biodiesel blends. Calorific values of biodiesel blends are lower than diesel about 10-15% and density and kinematic viscosity are higher than 5-7% and 15-20% respectively than diesel [8]. The fuel properties of different biodiesel blends are shown in Table 1.

Table 1: Fuel properties of tested biodiesel blends [14-17]

Biodiesel and blends	Fuel Properties			
	Calorific value (MJ/kg)	**Density (kg/m^3)**	**Kinematic viscosity (cst @ 40 ^oC)**	**Flash point (^oC)**
MB100	36.8	880	3.98	208
MB20	41.7	856	2.78	96
MGB100	42.3	862	4.25	113
MGB20	45	840	3.6	77
KB100	38.9	876	4.32	61
KB20	41.41	842	3.20	59
PB100	39.85	857	4.38	181
PB20	43.25	839	3.45	77
JB100	39.42	864	4.71	184
JB20	43.37	840	3.90	93
CIB100	39.17	871	4.98	92
CIB20	44.06	830	3.79	73
Diesel	45.60	834	3.4	68

From table, it is clear that by adding the biodiesel in diesel reduce the calorific value and increase the density, kinematic viscosity and flash point respectively, which increase the BSFC and reduce the BTE of the diesel engine by using the biodiesel blends. Higher oxygen content in biodiesel blend are advantages for combustion process, but higher density, viscosity and lower calorific value are disadvantageous for biodiesel blends for using in diesel engine operations.

3. RESULTS AND DISCUSSIONS

The effect of MGB_{20}, MB_{20}, PB_{20}, JB_{20}, CIB_{20} and KB_{20} blends and diesel on diesel engine performance and emissions characteristics are discussed below.

3.1 Performance characteristics

The diesel engine performance are measured in term of BSFC and BTE fuelled with different biodiesel blends, are discussed below:

3.1.1 Brake specific Fuel consumption (BSFC)

Figure 2, shows the BSFC for various biodiesel blends as MGB_{20}, MB_{20}, PB_{20}, JB_{20}, CIB_{20} and KB_{20} and compared to diesel [11]. All biodiesel shows the higher BSFC than diesel because biodiesel blends having lower calorific value, higher Kinematic viscosity and density. Higher BSFC contain by KB_{20} followed by MB_{20}, PB_{20}, JB_{20}, CIB_{20}, MGB_{20} and diesel is given as 680, 650, 600, 590, 560, 530 and 500 g/kWh respectively. BSFC is increase by 6, 12, 18, 20, 30 and 36% for MGB_{20}, CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to diesel. BSFC reduce by 5.66, 11.32, 13.20, 22.64 and 28.30% for CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to MGB_{20} blend [14-17]. Biodiesel blends improved ignition quality because of the presence of higher oxygen content, low viscosity and density of the biodiesel blends [13].

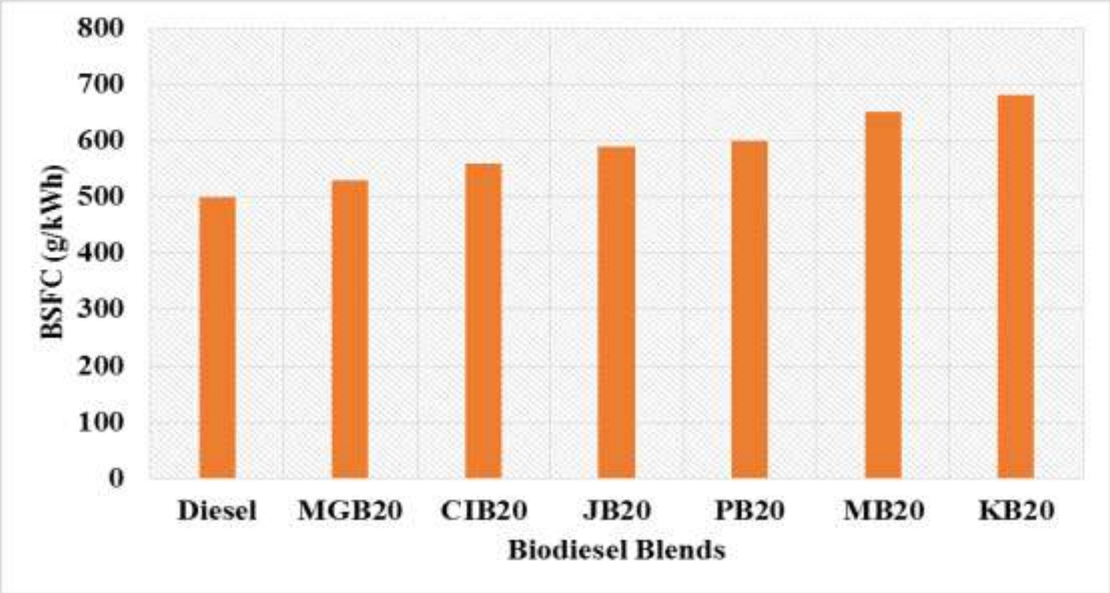

Figure 2: BSFC for various biodiesel blends with diesel [14-17]

3.1 Brake Thermal efficiency (BTE)

Figure 3, shows the BTE for various biodiesel blends as MGB_{20}, MB_{20}, PB_{20}, JB_{20}, CIB_{20} and KB_{20} and compared to diesel. BTE is known as fuel conversion efficiency that represent that the percentage of fuel converted into useful energy [10]. If different fuels are to be compared for the same engine BTE is major parameter instead of BSFC. The higher BTE is for diesel followed by MGB_{20}, CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} is 30, 28, 26, 25.3, 25, 23, 22.8% respectively. BTE is reduce by 6.67, 13.33, 15.67, 16.67, 23.33 and 24% for MGB_{20}, CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to diesel. BTE is reduce by 7.14, 9.64, 10.71, 17.85 and 18.58% for CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to MGB_{20} [14-17]. Lower BTE is influenced by the lower calorific value and higher kinematic viscosity of the biodiesel blends, the fuel having higher calorific value shows higher BTE and lower calorific value fuels shows low BTE in all conditions [11].

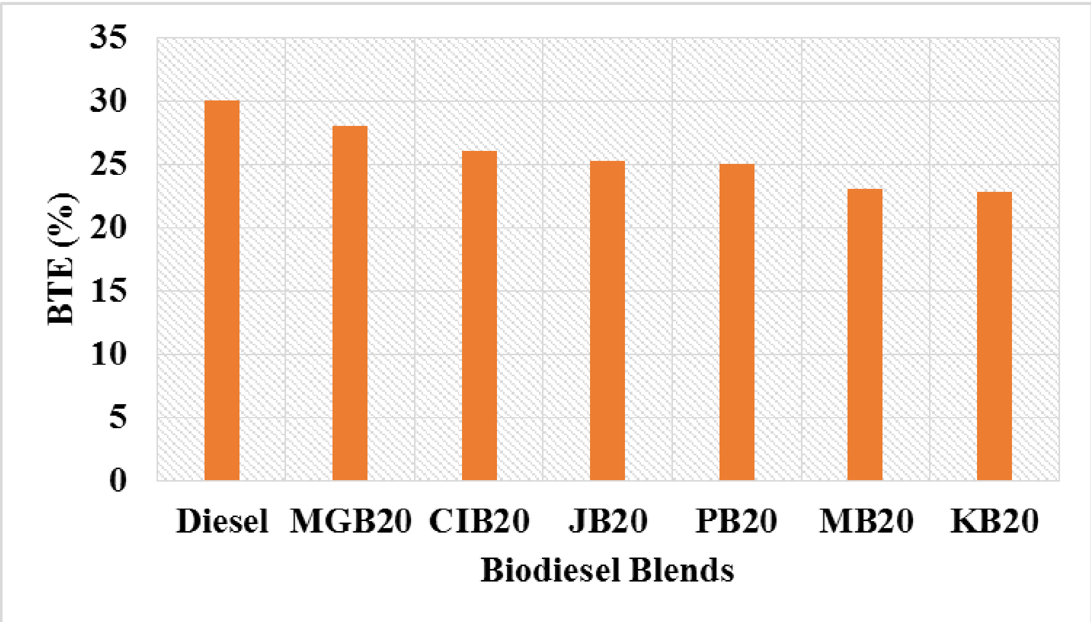

Figure 3: BTE for various biodiesel blends with diesel [14-17]

3.2 Emissions characteristics

The emissions characteristics of a diesel fuelled with biodiesel blends are given in term of Hydrocarbon (HC), Carbon monoxide (CO), Nitrogen oxide (NO_x) emissions and Smoke capacity compared to diesel fuel, are discussed below:

3.2.1 Hydrocarbon (HC) emission

Figure 4, shows the HC emissions for MGB_{20}, MB_{20}, PB_{20}, JB_{20}, CIB_{20} and KB_{20} and diesel. HC emissions are formed due to the incomplete burn of the fuels [10]. Highest HC emission is found by diesel followed by KB_{20}, CIB_{20}, JB_{20}, PB_{20}, MB_{20} and MGB_{20} is 48, 45, 43, 42, 41, 40 and 38 ppm respectively. HC reduce by 20.83, 10.42, 12.5, 14.58, 16.67 and 6.25% for MGB_{20}, CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} blends when compared to diesel and increase by 13.15, 10.52, 7.90, 5.26 and 18.42% for CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to MGB_{20} blend [14-17]. It is clear that reduction in HC is due to the higher oxygen content in the biodiesel blends which leads to higher combustion process [18].

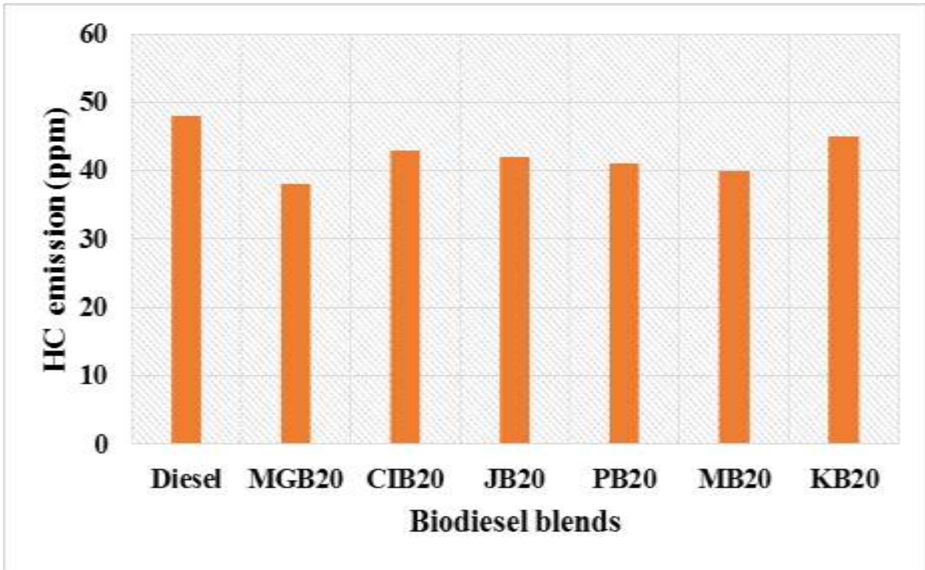

Figure 4: HC emissions for various biodiesel blends with diesel [14-17]

3.2.2 Carbon monoxide (CO) emission

Figure 5, shows the CO emissions for MGB_{20}, MB_{20}, PB_{20}, JB_{20}, CIB_{20} and KB_{20} and diesel. Highest CO emissions in found for diesel followed by PB_{20}, JB_{20}, KB_{20}, MB_{20}, CIB_{20} and MGB_{20} is 0.6, 0.52, 0.51, 0.50, 0.47, 0.45 and 0.35% respectively. CO can be produced during engine operation when charge combusts with lack of air flow and low flame temperature [19]. CO occurs at a rich air–fuel ratio when of O_2 unreachability to totally oxidize all CO proportion in the fuel. CO emission reduce by 41.67, 25, 15, 13.33, 21.67 and 16.67% for MGB_{20}, CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to diesel and increase by 28.57, 45.71, 48.57, 34.29 and 42.85% for CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to MGB_{20} blend [14-17]. The CO emissions for biodiesel blends are always lower than diesel for all operating conditions. CO produced during combustion of biodiesel is converted into CO_2 by taking the extra oxygen present in the biodiesel blend and thus reduced CO formation [17].

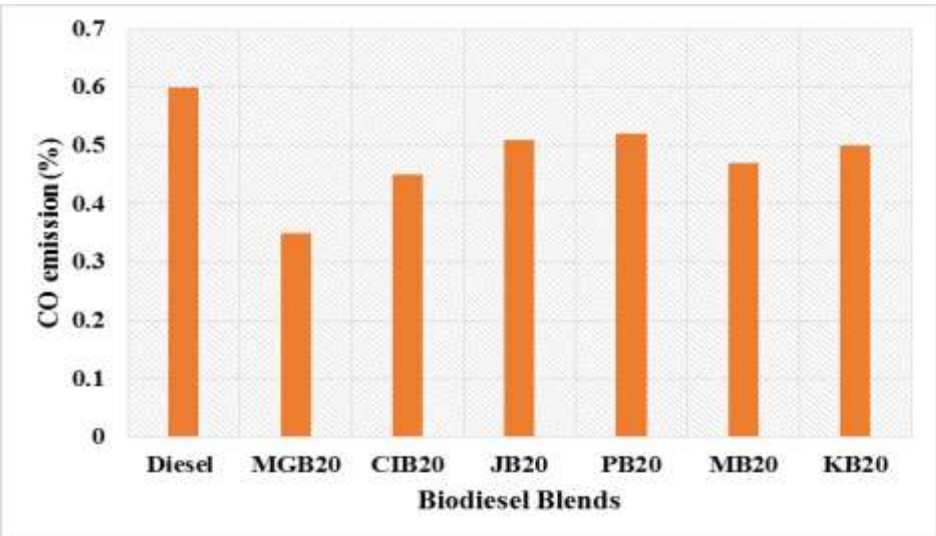

Figure 5: CO emissions for various biodiesel blends with diesel [14-17]

3.2.3 Nitrogen oxide (NO_x) emission

Figure 6, shows the NO_x emissions for MGB_{20}, MB_{20}, PB_{20}, JB_{20}, CIB_{20} and KB_{20} and diesel. NO_x emission is a form of nitric oxide (NO) and nitrogen dioxide (NO_2), which is produced when nitrogen and oxygen gases reacted with the air during combustion process. Highest NO_x emission for KB_{20} followed by MB_{20}, JB_{20}, PB_{20}, CIB_{20}, MGB_{20} and diesel is 450, 430, 400, 380, 340, 300 and 260 ppm respectively. NO_x formation is also governed by thermal, N_2O pathway, NNH, and fuel bound nitrogen mechanisms [19]. NO_x emissions increase by 15.38, 30.77, 53.85, 46.15, 65.38 and 73% for MGB_{20}, CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to diesel and increase by 13.33, 33.33, 26.67, 43.33 and 50% for CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to MGB_{20} blend [14-17]. The main reason for higher NO_x in biodiesel blends because it contain higher oxygen than diesel which improve the combustion process results higher fuel is required which increase the combustion temperature of the diesel engine by using the biodiesel blends [11].

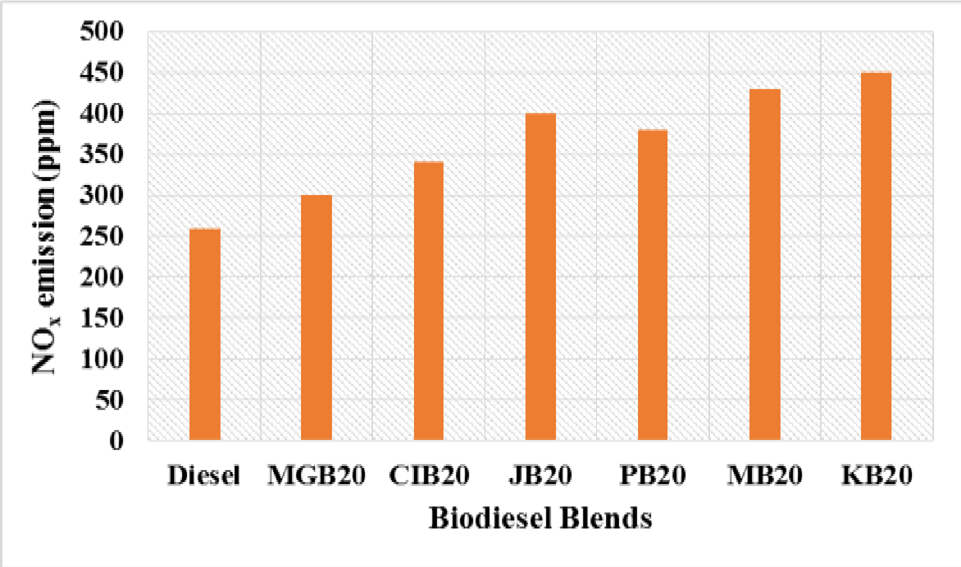

Figure 6: NO_x emissions for various biodiesel blends with diesel [14-17]

1. Smoke opacity

Figure 7, Smoke is an observable emission of diesel engine. The smoke capacity indicates the soot content in exhaust gasses. Biodiesel blends having lower smoke capacity than diesel, and it was increase with increase in the engine speeds [14]. Higher smoke capacity for diesel followed by MB_{20}, KB_{20}, PB_{20}, JB_{20}, CIB_{20} and MGB_{20} is 45, 40, 39, 39, 36, 35 and 32% respectively. Smoke opacity reduce by 28.89, 22.22, 20, 13.33, 11.11 and 13.33% for MGB_{20}, CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to diesel and increase by 9.37, 12.5, 21.87, 25 and 21.87% for CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} when compared to MGB_{20} blend [14-17].

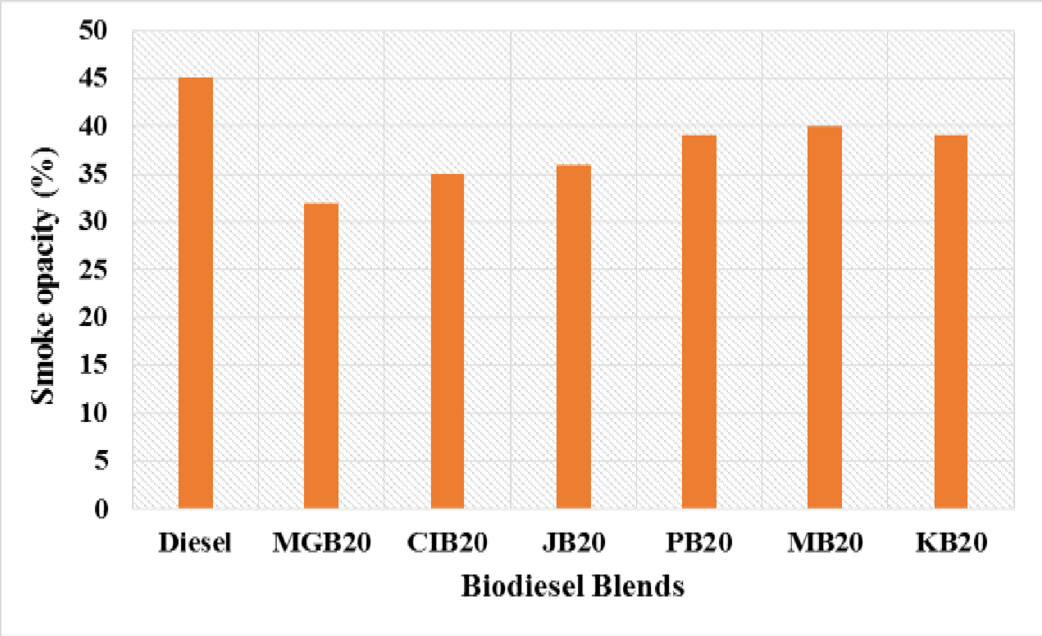

Figure 7: Smoke opacity for various biodiesel blends with diesel [14-17]

4. CONCLUSIONS

The performance and emission characteristics of MGB_{20}, CIB_{20}, JB_{20}, PB_{20}, MB_{20} and KB_{20} blends and compared to diesel, are summarized below:

1. Calorific value of biodiesel blends is reduce by increasing the biodiesel quantity in the biodiesel blend.
2. Highest BSFC is found for diesel which is 6% lower than MGB_{20} blend. MGB_{20} blend have minimum BSFC compared to other biodiesel blends.
3. BTE is reduce by 6.67% for MGB_{20} compared to diesel, and MGB_{20} blends have the highest BTE than other blends.
4. MGB_{20} blend have the lowest NO_x emissions compared to other biodiesel blends and increase the NO_x emission by 15.38% when compared to diesel.
5. HC emission is reduce by 20.83% for MGB_{20} compared to diesel and reduce by 18.42% for KB_{20}.
6. CO emission is the results of incomplete combustion of the fuel, which is increase by 41.67% for diesel compared to MGB_{20} blend.
7. Smoke opacity is the results of soot emission from diesel engine which is reduce by 28.89% for MGB_{20} compared to diesel.
8. From the above conclusion it is clear to use the Microalgae biodiesel blend (MGB_{20}) for diesel engine operation if HC, NO_x emission are the prime criteria.

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