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Comparative Analysis of Exhaust Emission from CI Engine Running on 20% Blends of Different Biodiesels

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Abstract Taking into account the rising cost of non-renewable energy source and ecological contamination, elective fuel is required. Looking for such fuel, biodiesel has drawn everybody's consideration. Biodiesel might be an enormous substitute for a non-renewable energy source. The current paper speaks to a relative examination of the biodiesel Karanja, Mahua and Jatropha in comparison with pure diesel (D_{100}). The three biodiesels were extracted from two-step transesterification process. Then 20 percentage blends of the biodiesels were used in CI engine separately at varying load. The Results were determined and afterwards compared on the ground of performance and emission from the engine. The outcomes demonstrate that the carbon monoxide (CO), hydrocarbon (HC), CO_2 and smoke created by K20 (karanja 20% blend), J20 (jatropha 20% blend) and M20 (mahua 20% blend) are lower than diesel (D_{100}). The brake thermal proficiency (BTE) for all the three biodiesels was found lower as comparison with D_{100}. The brake specific fuel consumption was lowest for D_{100}. Additionally, K20, J20 and M20 produce more NOx than diesel D_{100}. Likewise, EGT was found highest for D_{100}.

Keywords: *biodiesel, emission, performance, karanja, Jatropha and Mahua*

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1. Introduction

The principal source of power production in today’s life are fossil fuels. The fossil fuel proves to be a tremendous fuel but the problem with fossil fuel is their limited source and high pollution. So there is a need for alternative fuel that can replace fossil. In this search, the biodiesel is acquiring everyone’s attention. The use of edible vegetable can lead to food crisis so non-edible oil should be chosen for biodiesel production. Karanja, mahua and jatropha can be potential oil for biodiesel production. A yielding of more than 80% can be obtained by these oils [1,2]. Out of the various possible method, transesterification is an effective method for biodiesel production [3]. When the FFA in the biodiesel is higher than 2% it becomes necessary to use two-step transesterification otherwise there will be soap formation and lower-yielding [4]. The two-step transesterification method was performed using H_2SO4 as the acid catalyst and KOH as an alkali catalyst, which gave yielding of 99% of jatropha biodiesel. The produced biodiesel exhibit properties as per biodiesel standards [5]. In two-step transesterification, the soap formation is decreased by two times as compared to single-step [6]. In biodiesel production from mahua, a maximum yielding of 94.21% was extracted with 0.4% sodium methoxide, 6:1 molar ratio at 45°C after 45 minutes [7]. It was observed that reaction time, catalyst concentration and methanol/oil ratio significantly affect biodiesel yielding [8].

A lot of research has been done on the performance and emission characteristics of biodiesel running on the diesel engine. Most of the research indicates that the biodiesel is a potential alternate for pure diesel. The use of 100% biodiesel in the engine can produce some serious problem regarding engine life. In present work, 20 % blends of karanja (K20), Jatropha (J20) and Mahua (M20) have been used. Effectiveness evaluation and exhaust of diesel engine running at varying blending ratios have been reported by different researchers. Emissions like HC, CO_2, CO, smoke opacity and BTE are lower for biodiesel in comparison with diesel in almost every research and the NOx emission was found increased in comparison with D_{100} (diesel) [9,10,11,12,13,14,15]. In one other research, the BTE was found 3.65% less and NOx was found 9.86% more than diesel at CR 18 and full load conditions. it was also concluded that with the enhancement of blending ratio, the EGT and emission like NO_X, CO increases and the thermal efficiency decreases [16]. J20 was utilised as a fuel in a compression engine and it was observed that CO emission gets lowered 16.6%, the BSFC increased by 12.7%, NOx increased by 5.46% and smoke reduced by 22.8% in comparison with pure diesel [17]. In one other research, the HC and CO reduced by 24.6 % and 12.9 % respectively for B20 (20 % caster biodiesel). Also, the NOx emission increased by by11.8 % for B20 [18]. The blending ratio also affects emissions. On blending more than 50% the CO emission is greater for Manilkara Zapota biodiesel versus diesel [19]. The NOx for jatropha increased by 30% at 70% load and 2300 rpm [20].

2. Methodology

2.1. Biodiesel Production

All three biodiesels are produced from two-step transesterification process. The first step in transesterification involves reaction with methanol with the assistance of acid catalyst (H_2SO_4). In present work, methanol is used because it gives more yield and separation of glycerine is easier as compared with ethanol [21]. This process removes the FFA and moisture present in the raw oil. After this process, the mixture is made to settle down for one hour. The mixture is converted to two different phases. The upper phase liquid is separated and is used in the second step. The next step involves alkaline transesterification. In this step, a reaction is made between triglyceride and methanol using KOH as a catalyst in a controlled temperature. The mixture is then settled and is separated in two layers, i.e. crude biodiesel and glycerol. The unrefined biodiesel is then washed with hot water and the biodiesel is produced. The properties of the obtained biodiesels were similar to pure diesel. The biodiesel properties are shown in Table 1.

2.2. Experimental Setup

The tests are executed on a Kirloskar made single-cylinder, 4-stroke CI engine. The actual test kit is shown in the Figure 1. The engine delivers 5.4 KW at 1500 rpm. The set-up is coupled with a AVL 4000 Di- gas analyzer, which can detect CO, CO_2, HC, and NOx present in engine emission. Smoke opacity is noted using AVL 437 smoke meter.

3. Results and Discussion

3.1. Brake Thermal Efficiency (BTE)

The BTE specifies how efficiently an engine can convert the energy of the fuel to work output. The Figure 2 portrays the change of BTE at different load for the four fuels.

Table 1. Physical properties of Jatropha, Karanja and Mahua biodiesel

Properties	Jatropha Biodiesel	Mahua Biodiesel	Karanja biodiesel	Diesel
Density(Kg/m^3)	895	912	930	842
Kinematic Viscosity calculated @ 40°C (mm^2/s)	5.3	5.4	6.4	3.65
CV (KJ/kg)	36200	35100	34500	45200
Cloud Point in degree Celsius	5	6	4	2
Pour Point in degree Celsius	6	6	5.1	-2
Flash point in degree Celsius	189	194	201	69

Figure 1. Experimental setup

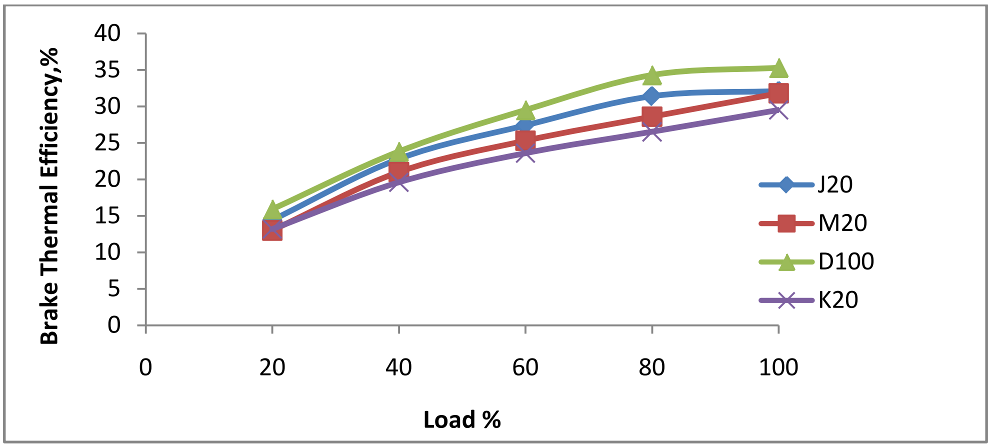

Figure 2. BTE vs Load

The figure depicts that the BTE for the three biodiesels is lower as compared to D_{100} (diesel). This is due to the reason that all three biodiesel has a high viscosity and low calorific value as compared to diesel. The BTE increases as the load are increased. At 100% loading the BTE for D_{100}, J20, M20 and K20 are 35.3%, 32.1%, 31.8% and 29.5% respectively.

3.2. Brake Specific Fuel Consumption

The BSFC is fuel burned per unit power produced by an engine. It is measured in Kg/KWh. It can be useful in comparing engines of different sizes. The effect of loading on BSFC of the D100, J20, M20 and K20 is shown in the Figure 3. The BSFC decreases as the load is increased. The BSFC for all the three biodiesels is less than diesel. This happens because all three biodiesel has a lower calorific value than D_{100} [17]. At peak load the BSFC for D100, J20, M20 and K20 are 0.19, 0.23, 0.29 and 0.33 Kg/KWh respectively.

3.3. CO Emission

The variation of CO emission wrt load is illustrated in Figure 4. The BSFC tends to increase for all the fuels as the load is enhanced. This happens because at higher load more rich fuel is burned [12].

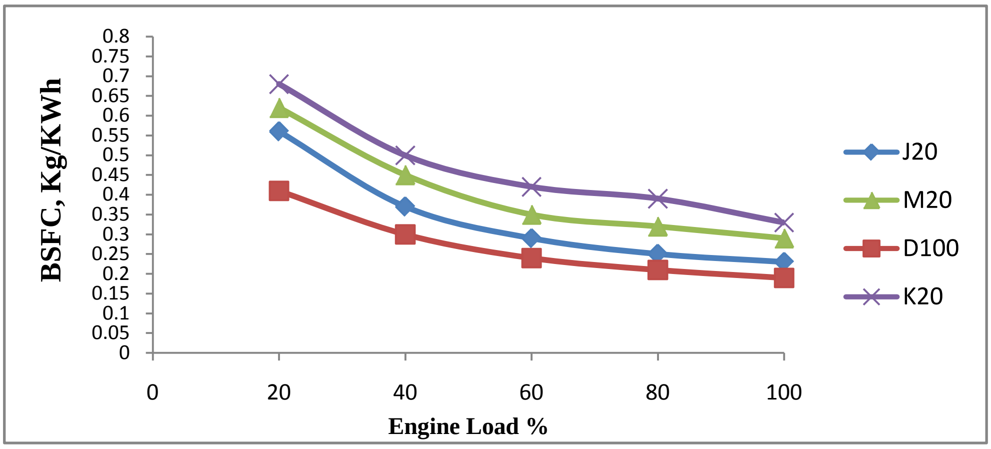

Figure 3. BSFC vs Load

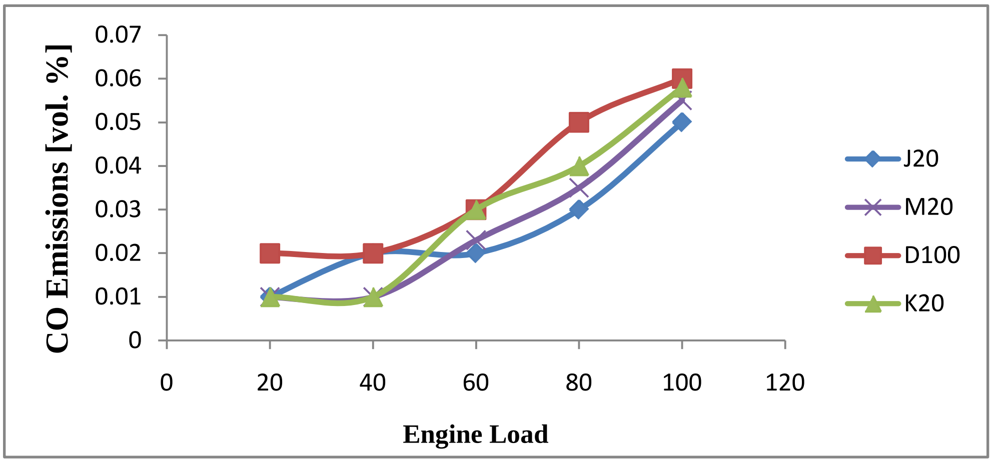

Figure 4. CO vs Load

The main reason for the production of the CO is incomplete combustion which occurs if there is a lack of O_2 in the fuel. The CO emission produced by all the three biodiesels is less than pure diesel. This happens because the diesel has less O_2 content as compared to the three biodiesels. The more O_2 in biodiesel exhibits more complete combustion and the CO emission reduces. At peak load the values of CO emission for D_{100}, J20, M20 and K20 are 0.06, 0.05, 0.58 and 0.055 volume % respectively. Similar trends were noted by other researchers [22].

3.4. CO_2 Emission

The CO_2 is produced when there is sufficient O_2 is available during the formation of CO [23]. The CO_2 emission for J20, M20 K20 and diesel is shown in the Figure 5. All three biodiesels exhibit lower CO_2 emissions as compared to pure diesel. The CO_2 emission increases as the load are increased. Similar patterns were noted by other researchers [24]. At peak load, the values for the CO_2 emission for D_{100}, J20, M20 and K20 are 4.1, 3.1, 3.8 and 3.5 in term of vol% respectively.

3.5. HC Emission

The variables influencing the HC emission are engine operating conditions, fuel spray characteristics, and availability of the O_2 in the engine cylinder [25]. Figure 6 illustrates the variation of HC emission wrt load. It can be noted that the HC emission increases as the load is increased. The HC emission for all the three biodiesels is less than D_{100} at all load values. This is due to the more O_2 present in the biodiesel, which leads to complete combustion. At peak load conditions the values of HC emission for, J20, K20 and M20 are 7.14, 3.3 and 7.14% less than D_{100} respectively.

3.6. NOx Emission

The factors influencing the NOx production are temperature, time available during combustion and oxygen concentration in the engine cylinder [26]. The NOx variation is shown in Figure 7. All three biodiesel shows higher NOx emission as compared to D_{100}. This happens because all the three biodiesel contains high oxygen content and this high oxygen available contributes to superior combustion [27]. At peak load conditions the values for the NOx for D_{100}, J20, K20 and M20 are 845, 992, 970 and 981ppm respectively.

3.7. Exhaust Gas Temperature

The EGT variation is portrayed in Figure 8. The EGT for all the four fuels increases on increasing the load. The EGT for all the three biodiesels is less than the pure diesel. This happens because the biodiesel has a high viscosity and exhibits poor combustion [11]. The values of the EGT at maximum load for D_{100}, J20, M20 and K20 are 455, 425, 432 and 440 °C respectively.

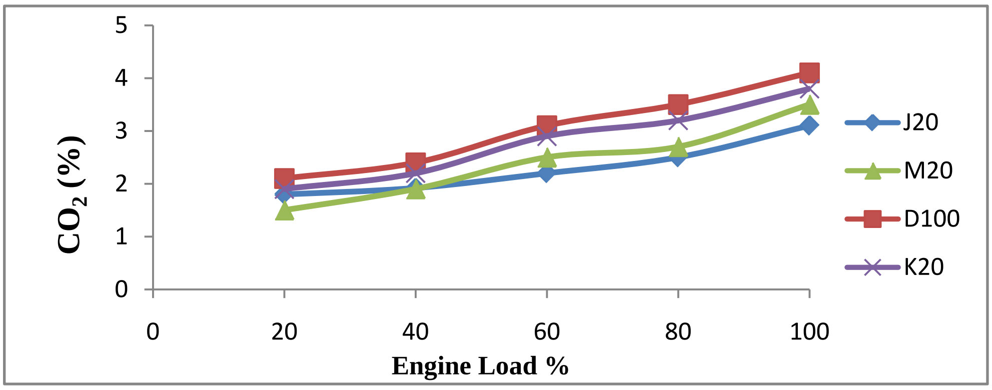

Figure 5. CO_2 vs Load

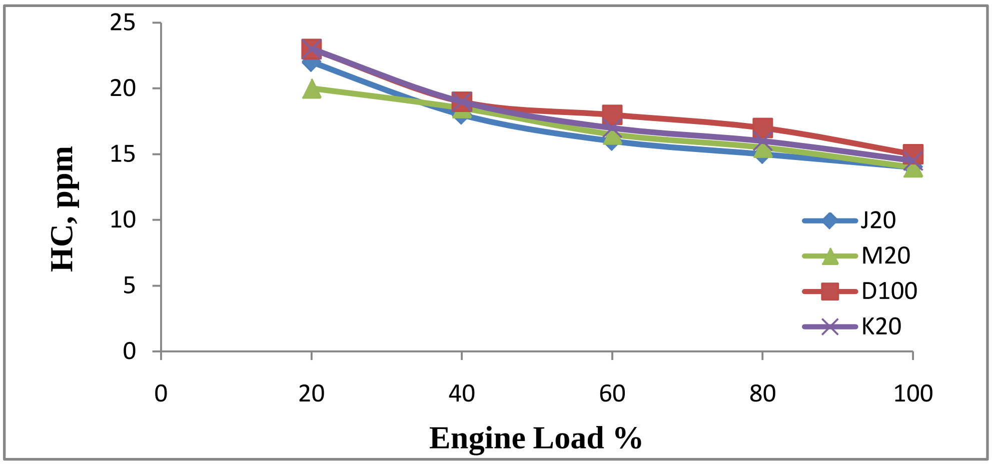

Figure 6. HC vs Load

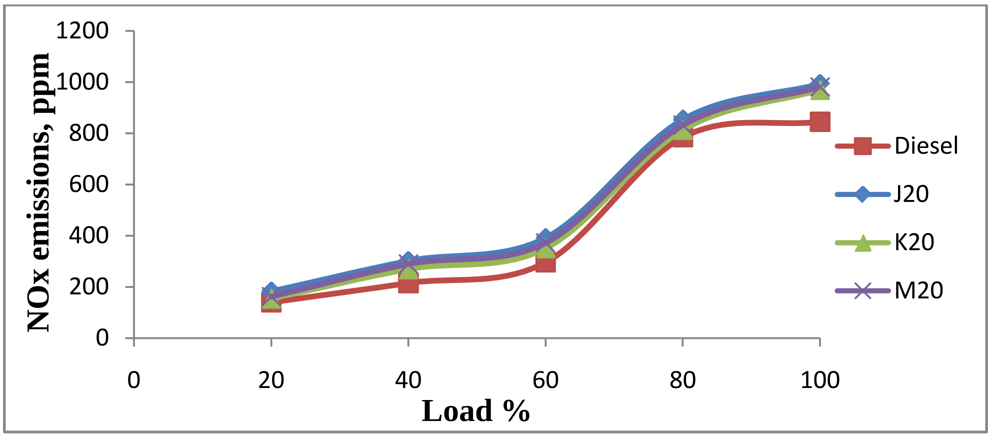

Figure 7. NOx vs Load

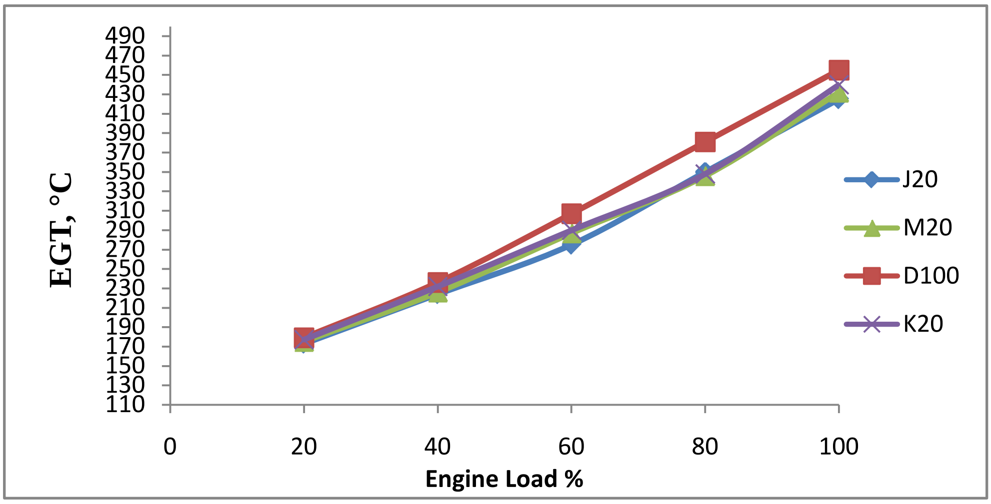

Figure 8. EGT vs Load

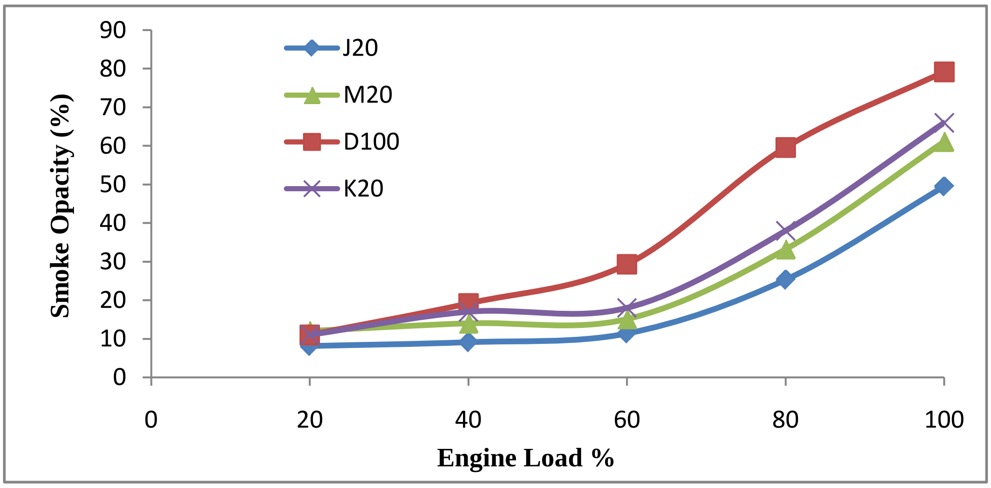

Figure 9. Smoke opacity vs Load

3.8. Smoke

The effect of change of load on smoke opacity is depicted in Figure 9 for the four fuels. The smoke tends to increases as the load is increased. This happens because at higher load more fuel is consumed in the cylinder [28]. The smoke for all the biodiesels is lower than D_{100}. The higher O_2 content of the biodiesels causes complete combustion and less smoke is produced [29]. At lower load, the gap is narrower but at higher load, the gap becomes wider. At maximum load, the values of smoke for D_{100}, J20, M20 and K20 are 79.2, 49.5, 61.1 and 66 % respectively.

4. Conclusion

The conclusion of the present study are summarised below:

1. The BTE of three biodiesels (J20, M20 and K20) is less than D_{100}. D_{100} produces 9.06%, 9.9% and

16.45 higher BTE than J20, M20 and K20 respectively.
2. The BSFC for D_{100} was found 21%, 52.6 and 73.6% less than J20, M20 and K20 respectively.
3. The CO emission for diesel was 16.6%, 3.33% and 8.3% higher than J20, K20 and M20 respectively.
4. The CO_2 for diesel was found 24.3%, 7.3% and 14.6% higher than J20, K20 and M20 respectively.
5. The HC emission for, J20, K20 and M20 are 7.14, 3.3 and 7.14% less than D_{100} respectively.
6. The NOx for diesel was 17.3%, 14.7% and 16% less than J20, K20 and M20 respectively.
7. The EGT and smoke for the three biodiesels were also less than D_{100}.

In term of emission and performance the J20, K20 and M20 proves to be a tremendous alternative for pure diesel. The 20% blends of all the three biodiesels can be used in diesel engine without any change in diesel design.

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