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Evaluation of Emission Characteristics of Biodiesel from Oils of Sandbox Seed and Moringa as Feedstock

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ABSTRACT

Biodiesel is a non–toxic, ecofriendly, biodegradable and renewable alternative fuel that can be used with little or no engine modifications. The objective of this paper is to investigate the emission characteristics of sandbox and moringa biodiesel and their blends on an internal combustion (IC) engine. The experimental work was carried out on a diesel engine by using biodiesel made from sandbox, moringa and its blends, comparing them to conventional diesel fuel. The fuels used in the analyses are of the following composition $BSM_{20} DF_{80}$, $BSM_{25} DF_{75}$, $BSM_{30} DF_{70}$, $BSM_{35} DF_{65}$, $BSM_{40} DF_{60}$, $BS_{20} DF_{80}$, $BS_{25} DF_{75}$, $BS_{30} DF_{70}$, $BS_{35} DF_{65}$, $BS_{40} DF_{60}$, $BM_{20} DF_{80}$, $BM_{25} DF_{75}$, $BM_{30} DF_{70}$, $BM_{35} DF_{65}$, $BM_{40} DF_{60}$ and diesel fuel (DF). The engine was operated over a range of engine speeds (1500rpm-2700rpm). Comprehensive analyses were carried out on major regulated emissions such as NOx, CO, smoke density, Engine noise level and HC. The results evidently indicate that the engine running with biodiesel and blends have higher NOx emission. However, the emissions of engine running on biodiesel and blends showed reduction in CO, smoke density, Engine noise level and HC respectively as compared to diesel fuel at various operating conditions. On the whole, methyl esters of sandbox, moringa and its blends with diesel fuel can be used as an alternative fuel for diesel in direct injection diesel engines without any significant engine modification.

1. Introduction

Biodiesel is a natural, biodegradable and renewable source. It is a clean burning diesel alternative fuel made of renewable sources such as new and used vegetable oils and animal fats. The interest of using alternative and renewable fuels in diesel engines has been improved recently due to a quick decrease in world petroleum reserves, rise in the prices of the conventional petroleum fuels and restrictions on exhaust emissions [1]. It has been reported by the US department of energy that the world's oil supply will reach its maximum production and midpoint of depletion sometime around the year 2020 [2]. Legislations have been passed in many countries, requiring diesel to contain a minimum percentage of biofuels. The Czech Republic proved to be the best, which insisted on 100% biofuel use for transportation [3]. The attractive characteristics of biodiesel include higher cetane number, non-toxic emissions, and bio-degradability, absence of sulphur and aromatic compounds and excellent lubricity [4]. Biodiesel is the fuel that can be produced from straight vegetable oils, edible and non-edible, recycled waste vegetable oils, and animal fat [5].

From the literature review, it is establish that most of the research works have been carried out on a number of unconventional fuels in diesel engines especially biodiesel produced from different kinds of vegetable oils, and very limited work has been done on biodiesel produced from non-edible seed. Ali et al (1995) tested twelve different blends of methyl tallowate, methyl soyate, ethanol and diesel fuel in a Cummins N14-410 diesel engine and found that there is no much difference in engine performance with blended fuels when compared with diesel fuel. In their study, maximum reduction in CO, HC and smoke density were obtained with blend [6, 7].

Kumar et al. [24], Kumar et al. [23], and Kerihuel et al.[25], applied ethanol in animal fat and methanol in jatropha oil, the results showed drastic reduction in smoke, NOx, HC and CO emissions when compared to neat fat and neat diesel at higher load conditions.

Aydin and Bayindir [8] using cottonseed oil methyl ester (CSOME) reported a decrease of CO, NO*x* and SO_2 emissions. The cost of feedstocks accounts about 60–80% of the total cost of biodiesel production. Therefore, the problem of high feedstock cost can also be mitigated by the selection of non-edible vegetable oil for the production of biodiesel [9]. Makame [10] tested clove stem oil (CSO) with diesel. The results indicate that performance parameters of the CSO-diesel blended fuels do not differs greatly from those of the neat diesel fuel. He observed slight power loss, combined with an increase in fuel consumption and low CO, HC and smoke density for CSO-diesel blended fuels [15, 16, 17].Gumus and Kasifoglu [11] tested an 8 kW, 3600 rpm diesel engine with apricot kernel oil methyl ester (ASKOME) and its blend with diesel fuel to evaluate performance and emissions. The results showed that with lower percent of ASKOME blend (B5, B20) shown a good improvement in the engine power and reduced BSEC. Higher percent of ASKOME (B100) reduces CO, HC emission and smoke density in exhaust effectively. But there was an adverse effect of NOx formation when compared with diesel fuel [11].

Smoke formation occurs primarily in the fuel rich zone of the cylinder, at high temperature and pressure. Smoke formation can be controlled by applying partially oxygenated fuel, which reduces locally over-rich regions (it is the region where the fuel is more than required; ie more than required air fuel ratio) [12]. When the engine runs under-load at WOT (Wide open throttle), maximum fuel is injected to supply maximum power, which is a rich mixture. Thus at higher load, an increased fuel-air ratio fuel is injected in large quantities and much of the unburnt fuel escape with the exhaust resulting in maximum smoke emission. Under less than 75% load condition, smoke formation was less and it increases with the increase in load [15]. Also, the difference in smoke level between the biodiesel and diesel is more significant at higher load in comparison to lower load [13].

The noise emission is different from that of air pollutants or other climate gases, as noise effects are restricted to the time of emission. The combustion noise is associated with the maximum pressure rise rate produced in the cylinder. Thus, higher pressure rise rate produces higher combustion noise and vice versa. The maximum pressure rise rate (dp/dΘ) can be decreased with the reduction in the ignition delay period so the engine will be running more smoothly [14].

2. Methodology

2.1 Production of biodiesel from sandbox and moringa seed oil

In this research study, one-step transesterification of sandbox and moringa seed oil with methanol was performed as KOH as catalyst. Sandbox and Moringa seed oil was converted into methyl esters through base-catalyzed transesterification with methanol in the presence of KOH as catalyst.

Before transesterification, sandbox and moringa seed oil was heated to around 120°C for 1 hour and then sediments and impurities were filtered with cloth filter. After this process, a sample of 500 g of sandbox and moringa seed oil, 95 g of methanol and 2 g of KOH were placed in a 1000 ml flat-bottom flask integrated with a magnetic stirrer heater, digital thermometer. This mixture was stirred rigorously and heated to 80°C for 2 hours, and then it was allowed to cool to room temperature for 18 hour. Then the ester and glycerol layers were separated in a separating funnel. Finally methyl ester of sandbox and moringa seed oil was purified with distilled water and drying to room temperature.

2.2. Fuel properties

Oil properties were determined using standard test methods according to ASTM, AOAC and EN standards. This test were carried out at National Research Institute for Chemical Technology, Zaria. Nigeria.

The properties of diesel fuel, sandbox and moringa seed methyl ester and its blend are given in Table 2. While blend composition of sandbox and moringa seed methyl ester is given in Table 1.

2.3. Blend preparation (Derived biodiesel with petrol diesel)

Blending of biodiesel was done using in-tank method of petroleum blending; the biodiesel obtained was blended with patrol diesel bought at NNPC/PPMC retail outlet in Hotoro in Kano, Kano State, North west, Nigeria. The blends were centrifuged for homogeneity before powering it with the engine. Blends were apportioned as indicated in Table 1.

Table 1: Generation of Blends for emission analysis

S/NO	BS	BM	DF	% OF BLENDS	REMARKS
1	10.00	10.00	80.00	$BS_{10} BM_{10} DF_{80}$	$BSM_{20} DF_{80}$
2	12.50	12.50	75.00	$BS_{12.5} BM_{12.5} DF_{75}$	$BSM_{25} DF_{75}$
3	15.00	15.00	70.00	$BS_{15} BM_{15} DF_{70}$	$BSM_{30} DF_{70}$
4	17.50	17.50	65.00	$BS_{17.5} BM_{17.5} DF_{65}$	$BSM_{35} DF_{65}$
5	20.00	20.00	60.00	$BS_{20} BM_{20} DF_{60}$	$BSM_{40} DF_{60}$
6	20.00	0.00	80.00	$BS_{20} BM_{0} DF_{80}$	$BS_{20} DF_{80}$
7	0.00	20.00	80.00	$BS_{0} BM_{20} DF_{80}$	$BM_{20} DF_{80}$
8	0.00	25.00	75.00	$BS_{0} BM_{25} DF_{75}$	$BM_{25} DF_{75}$
9	25.00	0.00	75.00	$BS_{25} BM_{0} DF_{75}$	$BS_{25} DF_{75}$
10	0.00	30.00	70.00	$BS_{0} BM_{30} DF_{70}$	$BM_{30} DF_{70}$
11	30.00	0.00	70.00	$BS_{30} BM_{0} DF_{70}$	$BS_{30} DF_{70}$
12	0.00	35.00	65.00	$BS_{0} BM_{35} DF_{65}$	$BM_{35} DF_{65}$
13	35.00	0.00	65.00	$BS_{35} BM_{0} DF_{65}$	$BS_{35} DF_{65}$
14	0.00	40.00	60.00	$BS_{0} BM_{40} DF_{60}$	$BM_{40} DF_{60}$
15	40.00	0.00	60.00	$BS_{40} BM_{0} DF_{60}$	$BS_{40} DF_{60}$
16	0.00	0.00	100.00	$BS_{0} BM_{0} DF_{100}$	DF_{100}

2.3. Experimental setup and experiments

The fuels used in this study include diesel fuel, biodiesel and biodiesel blends. The experiments were carried out by using conventional diesel fuel as the base line fuel(denoted as DF), 20% biodiesel + 80% diesel fuel (denoted as B20), 25% biodiesel + 75% diesel fuel(denoted as B25), 30% biodiesel + 70% diesel fuel (denoted as B30), 35% biodiesel + 65% diesel fuel(denoted as B35) and 40% biodiesel + 60% diesel fuel(denoted as B40) at different engine speed from 1500 rpm to 2700 rpm rated engine speed in approximate steps of 200 rpm. Three fuel tanks are used for storing diesel fuel and biodiesel separately with a burette and three way stop cock. The fuel is changed from diesel fuel to biodiesel by operating individual valves provided in each fuel tank and a three way stop cock. Before running the engine to a new fuel, it was allowed to run for sufficient time to consume the remaining part of fuel from the previous experiment. The engine was started initially with diesel fuel and warmed up to obtain its base parameters. Then, the same tests were performed with biodiesel and its blends. For each test fuel and in each speed approximately three times readings were taken to get an average value. To examine the emission characteristics, a portable BOSCH exhaust gas analyzer was used to measure the concentration of exhaust gases of the test engine such as hydrocarbon (HC) and oxide of nitrogen (NO_x) in part per million (ppm), carbon monoxide (CO) in percentage volume (% vol.) and smoke density was measured with an AVL smoke meter. To measure the noise level, NI Sound Level Measurement System was adopted. In this regard, the PCB Series of Array Microphones was employed.

Table 2: Chemo Physical Properties of Oil, Methylester of sandbox and moringa seed oils and diesel fuel used

Parameters	Diesel Fuel	Sandbox crude oil	Sandbox methyester	Moringa crude oil	Moringa methyester	ASTM D6751	EN 14214
Colour	Greenish blue	Golden yellow	Light yellow	Brown	Light brown	-	-
Moisture content %	-	-	0.14	-	0.18	0.05min	0.02min
Specific gravity	0.84		0.86		0.87	0.85-0.90	0.85
Kinematic viscosity (mm^2/s) at 40 ^0C	2.86		4.03		3.23	1.9-6.0	3.5-5.0
Acid value (mg KOH/g oil)		4.01	0.31	3.58	0.28	0.80 min	0.50 min
Cloud point ^0C	-	-	8.2	-	4.0	-15 to 5	-3 to 12
Flash point ^0C	85	-	197	-	250	100 – 170 min	120 min
Pour point ^0C	3.4	-	5.7	-	4.5	-35 to -15	-15 t0 16
Cetane number	48.4	-	62.12	-	57.90	47 min	51 min

3. Results and Discussion

Table 3 to Table 7 shows the emission results of fuel emission using experimental method (Gas analyser).

Table 3: Carbon monoxide emission

Speed(rpm)	1500	1700	1900	2100	2300	2500	2700
DF	0.80	0.72	0.65	0.58	0.49	0.38	0.30
BS20	0.60	0.56	0.58	0.55	0.45	0.29	0.26
BS25	0.55	0.50	0.55	0.49	0.42	0.28	0.24
BS30	0.50	0.47	0.48	0.46	0.38	0.28	0.24
BS35	0.48	0.45	0.46	0.43	0.36	0.27	0.23
BS40	0.45	0.41	0.45	0.40	0.34	0.26	0.22
BM20	0.55	0.53	0.47	0.42	0.37	0.29	0.20
BM25	0.50	0.52	0.45	0.40	0.35	0.30	0.19
BM30	0.46	0.42	0.37	0.34	0.30	0.25	0.18
BM35	0.40	0.36	0.34	0.31	0.25	0.23	0.17
BM40	0.36	0.30	0.28	0.25	0.22	0.21	0.16
BSM20	0.55	0.53	0.49	0.42	0.37	0.28	0.25
BSM25	0.50	0.47	0.45	0.40	0.35	0.28	0.23
BSM30	0.44	0.40	0.38	0.36	0.34	0.27	0.22
BSM35	0.44	0.39	0.36	0.35	0.32	0.26	0.22
BSM40	0.43	0.38	0.35	0.34	0.30	0.25	0.21

Table 4: Oxide of nitrogen (NOx) emission

Speed(rpm)	1500	1700	1900	2100	2300	2500	2700
DF	78	90	137	157	165	182	195

BS20	81	94	140	159	168	185	198
BS25	89	102	147	165	174	192	205
BS30	101	137	164	179	189	207	223
BS35	113	150	177	195	207	222	234
BS40	129	159	187	207	221	240	246
BM20	82	97	144	160	169	189	200
BM25	94	103	146	167	176	195	210
BM30	102	139	166	181	191	209	225
BM35	115	153	180	199	213	228	238
BM40	131	161	189	211	225	245	250
BSM20	80	93	139	158	167	184	197
BSM25	85	100	146	163	171	190	202
BSM30	100	135	162	175	187	205	220
BSM35	112	149	176	192	205	219	230
BSM40	117	155	182	201	215	231	242

Table 5: Unburnt hydrocarbon (HC) emission

Speed(rpm)	1500	1700	1900	2100	2300	2500	2700
DF	12.29	12.89	14.05	15.65	17.67	18.97	20.95
BS20	8.02	8.43	9.65	11.00	13.04	14.06	15.87
BS25	8.85	9.30	10.55	11.92	13.98	15.02	16.84
BS30	9.30	9.85	11.02	12.47	14.55	15.56	17.44
BS35	9.91	10.45	11.59	13.14	15.15	16.31	18.22
BS40	10.49	11.08	12.23	13.82	15.83	17.03	18.99
BM20	8.21	8.64	9.87	11.23	13.27	14.31	16.11
BM25	8.95	9.45	10.65	12.09	14.15	15.15	17.03
BM30	9.51	10.05	11.24	12.69	14.78	15.80	17.70
BM35	10.00	10.67	11.81	13.38	15.38	16.54	18.47
BM40	10.79	11.39	12.55	14.15	16.17	17.37	19.35
BSM20	7.81	8.22	9.42	10.77	12.80	13.81	15.60
BSM25	8.70	9.14	10.38	11.74	13.79	14.83	16.64
BSM30	9.15	9.65	10.86	12.31	14.38	15.38	17.25
BSM35	9.70	10.24	11.35	12.90	14.90	16.05	17.95
BSM40	10.20	10.88	12.03	13.60	15.61	16.79	18.74

Table 6: Smoke density

Speed(rpm)	1500	1700	1900	2100	2300	2500	2700
DF	40.00	45.00	60.00	72.00	80.00	85.00	90.00
BS20	38.00	43.00	57.00	68.00	76.00	81.00	87.00
BS25	32.00	35.00	48.00	61.00	69.00	75.00	80.00
BS30	28.50	31.60	44.00	55.00	62.00	75.00	80.00
BS35	27.00	28.00	41.00	50.00	56.00	66.00	72.00
BS40	24.00	25.00	34.00	44.00	50.00	57.00	64.00
BM20	36.00	40.00	54.00	67.00	73.00	79.00	84.00
BM25	31.50	35.00	46.00	60.00	67.00	74.00	78.00
BM30	29.00	31.00	43.00	52.00	60.00	72.00	77.00
BM35	25.00	28.00	40.00	48.00	54.00	63.00	70.00
BM40	23.00	24.00	32.00	44.00	50.00	55.00	62.00
BSM20	34.00	37.50	51.00	64.00	72.00	77.00	82.00
BSM25	30.00	33.80	46.00	58.00	65.00	77.00	82.00
BSM30	28.00	29.00	43.00	50.00	60.00	70.00	75.00
BSM35	25.00	27.00	38.00	47.00	53.00	60.00	68.00
BSM40	22.00	23.00	30.00	40.00	46.00	50.00	58.00

Table 7: Engine noise emission

Speed(rpm)	1500	1700	1900	2100	2300	2500	2700
DF	86.00	89.00	96.00	98.00	110.00	118.00	128.00
BS20	83.00	87.00	92.00	95.00	106.00	114.00	124.00
BS25	81.00	85.00	90.00	93.00	103.00	111.00	120.00
BS30	79.00	83.00	87.00	90.00	99.00	107.00	116.00
BS35	76.00	80.00	84.00	87.00	95.00	103.00	111.00
BS40	73.00	76.00	80.00	84.00	91.00	97.00	106.00
BM20	82.00	86.00	91.00	94.00	105.00	113.00	123.00
BM25	81.00	84.00	90.00	93.00	103.00	111.00	120.00
BM30	78.00	82.00	87.00	90.00	99.00	106.00	115.00
BM35	75.00	78.00	83.00	86.00	94.00	101.00	110.00
BM40	72.00	76.00	80.00	83.00	91.00	97.00	106.00
BSM20	85.00	89.00	95.00	97.00	108.00	117.00	127.00
BSM25	84.00	87.00	93.00	96.00	106.00	115.00	125.00
BSM30	81.00	84.00	90.00	93.00	103.00	111.00	120.00
BSM35	79.00	83.00	88.00	91.00	99.00	107.00	116.00
BSM40	73.00	77.00	81.00	84.00	91.00	98.00	107.00

Table 8: Technical specifications of diesel engine used

Engine brand name	Multi-cylinder Engine Test Bed
Manufacturer	Cussons Company, England
Number of cylinders	4.00
Cylinder stroke	88.30 mm
Cylinder bore	75.00 mm
Rated speed	2700 rpm
Compression ratio	18:1
Cooling system	Air cooled
Displacement	1560^{oc}

3.1 Emission analysis

3.1.1 Carbon monoxide (CO) emission

Figure 1, shows the variation of the percentage of carbon monoxide (CO) emission for diesel fuel (DF), biodiesel of sandbox (BS), biodiesel of moringa (BM), and blends of biodiesel of sandbox and moringa (BSM). At engine speed of 1500, 2100 and 2700 rpm were 0.80%, 0.60%, 0.55%, 0.55% for 1500 rpm, 0.58%, 0.55%, 0.42%, 0.42% for 2100 rpm, 0.30%, 0.26%, 0.20%, and 0.25% for 2700 rpm at DF, BS20, BM20 and BSM20. Carbon monoxide (CO) reduced by 0.20%, 0.25%, 0.25% for 1500 rpm, Carbon monoxide (CO) reduced 0.30%, 0.16%, 0.16% for 2100 rpm, Carbon monoxide (CO) reduced 0.40%, 0.10%, 0.05% for 2700 rpm. The engine emits less CO using biodiesel as compared to that of diesel fuel under all conditions. With increasing biodiesel percentage BSM40, BS40, BM40, BSM35, BS35, BM35, BSM30, BS30, BM30, BSM25, BS25, BM25, BSM20, BS20 and BM20, CO emission level decreases. The amount of oxygen content in biodiesel helps for the combustion which is in agreement with reported work of some authors [15], [16] and [17].

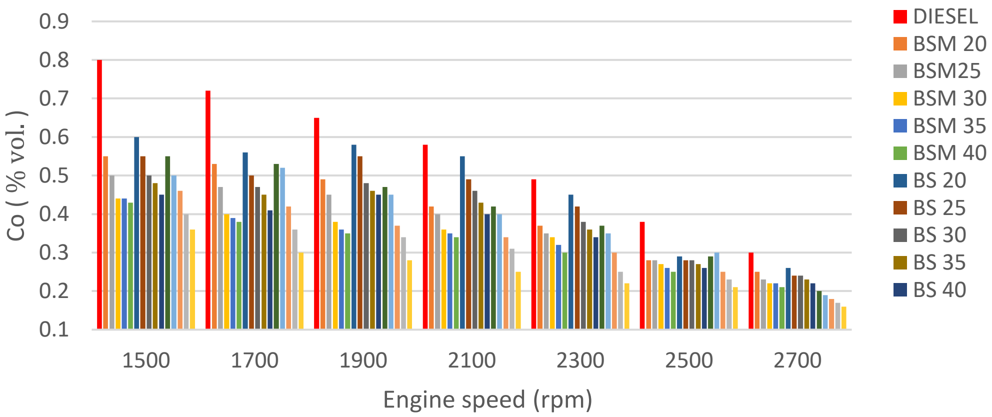

Figure 1: Variations of engine speed on carbon monoxide

3.1.2 Oxide of nitrogen (NOx) emission

Figure 2, show percentage of Oxide of nitrogen (NOx) emission for diesel fuel (DF), biodiesel of sandbox (BS), biodiesel of moringa (BM) and blends of biodiesel of sandbox and moringa (BSM). At engine speed of 1500, 2100 and 2700 rpm were 78 ppm, 81 ppm, 82 ppm, 80 ppm for 1500 rpm, 157 ppm, 159 ppm, 160 ppm, 158 ppm for 2100 rpm, 195 ppm, 198 ppm, 200 ppm, 197 ppm for 2700 rpm at DF, BS20, BM20 and BSM20. Oxide of nitrogen (NOx) emission increased by 3.70%, 4.88%, 2.50% for 1500 rpm, 1.26%, 1.88%, 0.63% for 2100 rpm,1.52%, 2.50%, 1.02% for 2700 rpm. The engine emits higher oxide of nitrogen (NOx) using biodiesel as compared to that of diesel fuel under all conditions. With increasing biodiesel percentage, NO_x emission also increases. In all the biodiesel blends, BSM20, BS20 and BM20 gives the minimum NO_x emission. These could be attributed to an increase exhaust gas temperature due to lower heat transfer and higher oxygen concentration in biodiesel improve the combustion which increases the flame temperature of the engine cylinder [18, 19, 20 and 21].

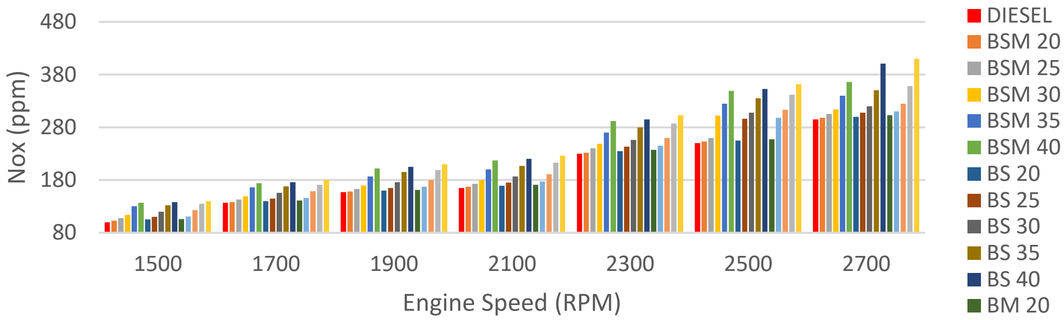

Figure 2: Variations of engine speed on oxide of nitrogen

3.1.3. Hydrocarbon (HC) emission

Figure 3, shows percentage of hydrocarbon (HC) emission for diesel fuel (DF), biodiesel of sandbox (BS), biodiesel of moringa (BM) and blends of biodiesel of sandbox and moringa (BSM). At engine speed of 1500, 2100 and 2700 rpm were 12.29 ppm, 8.020 ppm, 8.21 ppm, 7.81 ppm for 1500 rpm, 15.65 ppm, 11.00 ppm, 11.23 ppm, 10.77 ppm for 2100 rpm, 20.95 ppm, 15.87 ppm, 16.11 ppm, 15.60 ppm for 2700 rpm at DF, BS20, BM20 and BSM20. Hydrocarbon (HC) emission reduced by 34.74%, 33.20%, 36.45% for 1500 rpm, 29.71%, 28.24%, 31.18% for 2100 rpm, 24.25%, 23.10%, 25.54% for 2700 rpm. The relation between load and Hydrocarbon (HC) increased by increasing the engine speed for each blend. All the Blends give lower HC than diesel. The reduction in HC is mainly due to the improved combustion quality for biodiesel diesel blends with the presence of excess oxygen atom in biodiesel. The higher cetane number of biodiesel diesel blends also caused a decrease in HC emissions and decrease in combustion delay [19, 15 and 22].

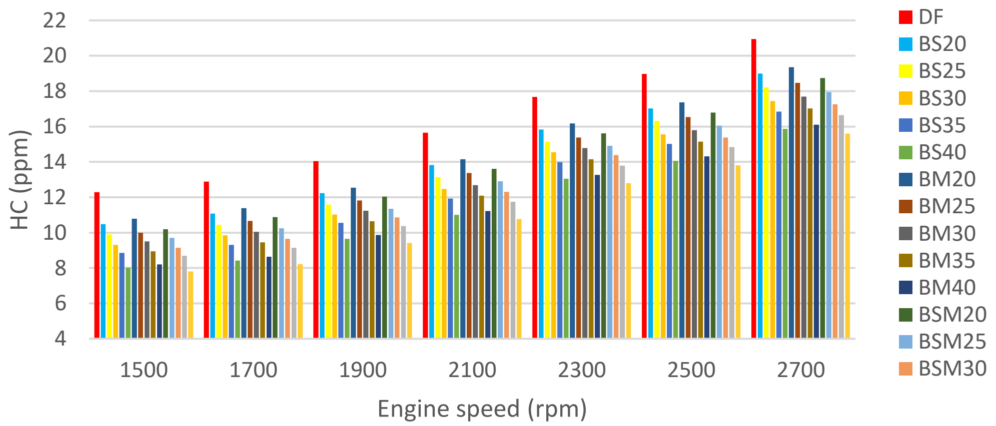

Figure 3: Variations of engine speed on hydrocarbon (HC) emission

3.1.4. Smoke density

The variation in smoke density with diesel fuel, biodiesel and its blend is shown in Figure 4. As shown in the Figure 4, the difference in smoke level between the biodiesel and diesel is more significant at higher load in comparison to lower load. For all tested engine condition, the smoke emission decreases consistently with the increasing amount of biodiesel in the blend. The maximum and minimum reduction in smoke level at different engine speed was found as 31.40% and 6.61% respectively. The reduction in smoke level at higher speed may be due to better combustion at higher load and more biodiesel is required. Other reason may be the difference in chemical structure and presence of oxygen in the biodiesel.

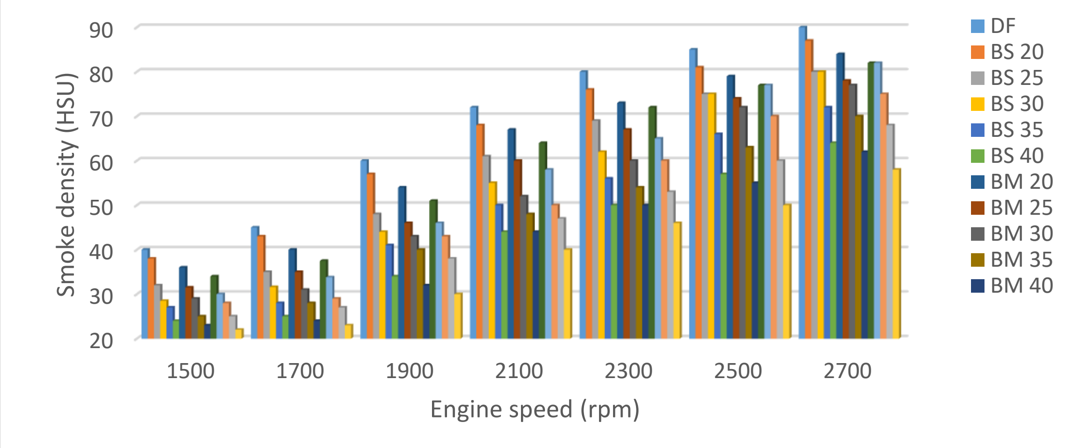

Figure 4: The difference in smoke level between the biodiesel and diesel

3.1.5. Noise emission

Figure 5, shows that the sound level for all blend fuels is decreased when compared to DF and increased as the engine speed increased for each fuel sample tested.

Lower sound level compared to DF may be attributed due to some higher viscosities of blend fuels which produced lubricity and damping and thus resulted in decrease of sound level. Secondly, higher cetane number of blend fuels may decrease the ignition delay which causes the maximum pressure rise rate to decrease so the engine produced lower sound level. Besides, it was noted that engine noise emissions were reduced with the increase in fuel oxygen content in blend fuels due to improved combustion efficiency.

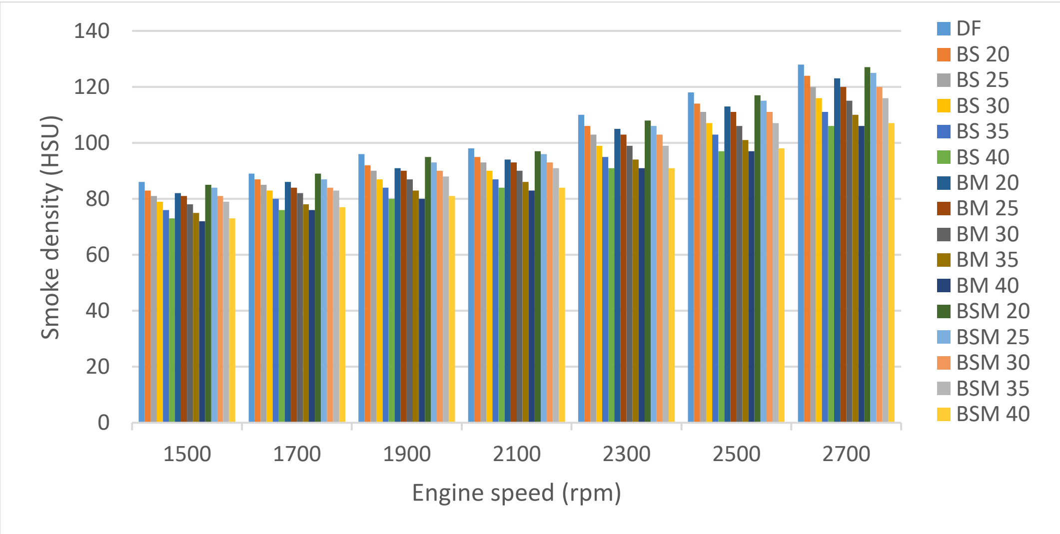

Figure 5: Variation of sound level of all blends

4. Conclusion

This paper presents the result of engine evaluation of emission characteristics of biodiesel from oils of sandbox seed and moringa as feedstock. The study have shown that CO emissions reduce when using biodiesel due to the higher oxygen content and the lower carbon to hydrogen ratio in biodiesel compared to diesel. HC emissions reduce when biodiesel is fueled instead of diesel. This reduction is mainly contributed to the higher oxygen content of biodiesel, but the advance in injection and combustion of biodiesel also favour the lower HC emissions. NOx emissions increase when using biodiesel. This increase is mainly due to higher oxygen content for biodiesel. Moreover, the cetane number and different injection characteristics also have an impact on NOx emissions for biodiesel. Noise increases as engine speed increases but reduces with increase in biodiesel. Smoke emission decreases consistently with the increasing amount of biodiesel in the blend. Overall, biodiesel, especially for the blends with a small portion of conventional fuel, is technically feasible as an alternative fuel in internal combustion engines with no or minor modifications of engine. For ecological and economic reasons, their popularity may soon grow.

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6. Conflict of Interest

There is no conflict of interest associated with this work.

References

[1] Hulwanm, D.B. and Joshi, S.V. (2011).“Performance, emission and combustion characteristic of a multicylinder DI diesel engine running on diesel–ethanol–biodiesel blends of high ethanol content”. *Applied Energy* 8 (12), pp: 5042–5055.

[2] Jindal, S., Nandwana, B.P., Rathore, N.S. and Vashistha, V. (2010). “Experimental investigation of the effect of compression ratio and injection pressure in a direct injection diesel engine running on Jatropha methylester”. *Appl Therm Eng* 30, pp: 442–448.

[3] Ganapathy, T., Gakkhar, R.P. and Murugesan, K. (2011).“Influence of injection timing on performance, combustion and emission characteristics of Jatropha biodiesel engine”. *Appl Energ* ; 88 (12), pp: 4376–86.

[4] Anand, K., Sharma, R.P. and Mehta, P.S. (2011).“Experimental investigations on combustion, performance and emissions characteristics of neat karanji biodiesel and its methanol blend in a diesel engine”. *Biomass and Bioenergy* ; 35(1) pp: 533-541.

[5] Liaquat, A.M., Kalam, M.A., Masjuki, H.H. and Jayed, M.H. (2010). “Potential emissions reduction in road transport sector using biofuel in developing countries” *Atmos Environ* 2010; 44; pp: 3869-3877.

[6] Ali, Y., Eskridge, K. M. and Hanna, M. A. (1995). Testing of alternative diesel fuel from tallow and soybean oil in Cummins N14-410 diesel engine. Bioresource Technol. 1995; 52: 237-43.

[7] Ali Y, Hanna M.A, Borg, J. E. (1995). Optimization of diesel, methyl tallowate and ethanol blend for reducing emissions from diesel engine. Bio resource Technol.

[8] [Aydin, H. and Bayindir, H. (2010). “Performance and emission analysis of cottonseed oil methyl ester in a diesel engine” *Renew Energ* ; 35; pp: 588-592.

[9] Varanda, M.G., Pinto, G. and Martins, F. (2011). “Life cycle analysis of biodiesel production”. *Fuel Process Technol*; *92; pp*: 1087–1094.

[10] [Makame, M. (2008). “Performance, emission and economic assessment of clove stem oil- diesel blended fuels as alternative fuels for diesel engines”. Renewable Energy; 33; pp: 871-882.

[11] Gumus, M. and Kasifoglu, S. (2010) “Performance and emission evaluation of a compression ignition engine using a biodiesel (apricot seed kernel oil methyl ester) and its blends with diesel fuel”. Biomass Bioenergy.; 34; pp: 134-139.

[12] Puhan, S., Vedaraman, N., Sankaranarayanan,G., and Bharat Rama, B.V. (2005)"Performance and emission study of Mahua oil (Madhuca indica oil) ethyl ester in a 4-stroke natural aspirated direct injection diesel engine". Renew. Energ.; 30, pp: 1269-1278.
[13] Sethi, V.P., and Salaria, K.S., (2004). "Exhaust analysis and performance of a single cylinder engine run on dual fuels". IE (I) J.; 85, pp: 1- 7.
[14] Mohamed, S.Y., Selim, S.B., Al-Omari, Abdullah, A. J. and Al-Aseery,(2009). "Effects of Steam Injection to Dual Fuel Engine on Performance, Noise and Exhaust Emission". SAE Paper -01-1831.
[15] Liaquat, A. M., Masjuki, H. H., Kalam, M. A., Varman,M. and Hazrat, M. A. (2012). "Experimental Analysis on Engine Performance and Emission Characteristics Using Biodiesel Obtained from Non-Edible Oil"International Review of Mechanical Engineering (I.RE.M.E.) " Vol. 6.
[16] Cengiz, O. and Sehmus, A. (2009). "Biodiesel production from inedible animal tallowand an experimental investigation of its use as alternative fuel in a direct injection diesel engine". Appl. Energy.86:2114-2120.
[17] An, H., Yang, W.N., Chou, S.K., and Chua, K.J. (2012) "Combustion and Emissions Characteristics of Diesel Engine Fuelled by Biodiesel at Partial Load Conditions". Applied Energy. Vol. 99 pp363-371.
[18] Sethi, V.P. and Salaria, K.S., (2004). "Exhaust analysis and performance of a single cylinder engine run on dual fuels". IE (I) J.; 85, pp: 1- 7.
[19] Qi, D.H., Chen, H., Geng, L.M., and Bian,Y.Z. (2011). "Effect of diethyl ether and ethanol additives on the combustion and emission Characteristics of biodiesel-diesel blended fuel engine". Renewable Energy. 36 pp: 1252-1258.
[20] Lei, Z., Cheung, C.S., Zhang, W.G., and Huang Z. (2011). "Effect of charge dilution on gaseous and particulate emissions from a diesel engine fuelled with biodiesel and biodiesel blended with methanol and ethanol". Applied Thermal Engineering; Vol. 31 pp: 2271-2278
[21] Jaichandar, S. and Annamalai, K. (2011). "The Status of Biodiesel as an Alternative Fuel for Diesel Engine - An Overview". Journal of Sustainable Energy & Environment, vol. *2: pp*71-75.
[22] Mofijur, M., Masjuki, H. H., Kalam, M.A., Atabani, A.E., Fattah, I.M.R., and Mobarak, H.M. (2014). "Comparative evaluation of performance and emission characteristics of Moringa oleifera and palm oil based biodiesel in a diesel engine". Industrial Crops and Products, Vol.53; pp: 78–84.
[23] Kumar MS, Ramesh A, Nagalingam B. (2003). An experimental comparison of methods to use methanol and jatropha oil in a compression ignition engine. Biomass Bio energy; 25: 309-18.
[24] Kumar MS, Kerihuel A, Bellettre J, Tazerout M. (2006). Ethanol animal fat emulsions as a diesel engine fuel-part 2: engine test analysis. Fuel.85:2646-52.
[25] Kerihuel A, Kumar MS, Bellettre J, Tazerout M. (2006). Ethanol animal fat emulsions as a diesel engine fuel-part 1: formulations and influential parameters. Fuel. 85:2640-5.