Diesel Engine Performance Evaluation and Emission Analysis Using Gmelina Seed Oil Biodiesel

Umeuzuegbu J.C.,[1] Ezennajiego E.E.,[1] Onukwuli O.D.[2]
Department of Chemical Engineering, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.[1]
Department of Chemical Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.[3]

Abstract:- Biodiesel is emerging as the promising choice for compression ignition engine due to its renewable, environmentally friendly and biodegradable nature, with superior emission characteristics. However, the true test of the suitability of biodiesel in a diesel engine lies with engine evaluated performance and emission test. This research work focused on the engine performance evaluation and emission test of gmelina seed oil fatty acid methyl ester (GSOFAME) or bidiesel on diesel engine. GSOFAME was produced using methanol and sodium hydroxide (NaOH) catalyst. The physiochemical property of the biodiesel was determined based on American standards for testing and materials (ASTM). The engine performance was carried out on Perkins 4:108 4 stroke diesel engine using GSOFAME, diesel and their blends. The fuel properties of the GSOFAME which are within the ASTM standard limits were determined as density 874kgm^3, kinematic viscosity 4.975mm^{2}s^{-1} at 40^{0}C, cetane number 64.2, flash point 178^{0}C, cloud point 5^{0}C, pour point 3^{0}C, acid value 0.24mgKOHg^{-1}, calorific value 38.33MJ/Kg. The engine performance evaluation revealed that the BSFC of the blends decreased with increase in engine speed and attained minimum value at 1600rpm for B0-B40 and 1800rpm for B60-B100 and then started increasing with increase in speed. The BTH and BP increased with increase in engine speed and attained maximum values at1600rpm for B0-B40 and 1800rpm for B60-B100 and then started decreasing with increase in engine speed. Again the BSFC decreased with increase in engine load and attained minimum value at 70% of the maximum load or 70kg and then started increasing with increase in load. The BTH and BP increased with increase in engine load and peaked at 70% of the maximum load when they started decreasing with increase in load. The results showed that the BSFC, BTH and BP of B20 are close to that of B0. However the BTH of B20 and blends with less biodiesel fraction proved superior to that of B0 by exhibiting higher BTH. The engine emission test shows that CO, HC and NOx emission increased with increase in load for B0-B100. At a specific load, CO and HC decrease with increase biodiesel fraction while NOx emission increased with increase in biodiesel fraction. The overall result shows that B20 and blends with less biodiesel fraction can be used directly in a diesel engine without any engine modification. Again the low emission from GSOFAME shows that it will have minor negative impact on the environment.

***Keywords*:-** *Engine Emission Test, Engine Performance Test, Engine Load, GSOFAME, Transesterification.*

I. INTRODUCTION

The rapid increase in world population followed by high spate of industrialization has resulted in high rate of depletion of fossil fuel. In addition, petroleum is beset with other problems such as none-renewable, none-biodegradable and environmentally unfriendly nature. These draw-backs have elicited research into the use of alternative energy to fill these gaps. Biodiesel is a mono-alkyl ester of long chain fatty acid and has promised to be a suitable alternative to replace diesel [1]. Various methods have been suggested for production of biodiesel including micro-emulsion with alcohol, catalytic cracking, pyrolysis and transesterification [2]-[5]. Presently, transesterification process is employed for biodiesel production because of its high efficiency. The advantages of biodiesel over fossil fuel are, being renewable, biodegradable, environmentally friendly, high cetane number and high lubricity [6]. However, biodiesel has its own drawbacks which include high density and viscosity, poor cold-flow properties [6] Diesel engines are the prime movers in the transportation, power generation, construction industries etc. As an alternative to diesel fuel, the engine performance and emission characteristics of biodiesel in diesel engine need to be analyzed first before fueling it. Many researchers have investigated the performance and emission characteristics of diesel engine using biodiesel from various sources [7]-[13]. This research work focused on the compression ignition engine performance and emission characteristics when fuelled with gmelina seed oil biodiesel. The gmelina seed oil was obtained by solvent extraction of gmelina seeds. The oil obtained was then pretreated or esterified and then transeserified to the biodiesel. The diesel engine performance was evaluated by comparison of the plots of the engine performance characteristics, brake specific fuel consumption (BSFC), brake thermal efficiency (BTE) and brake power(BP) with engine speed and engine load of the biodiesel and the blends with that of the diesel. The emissions from GSOFAME, diesel and the blends were characterize as carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NOx) using digital gas analyzer (Testo XL 450).

II. MATERIALS AND METHODS

A Materials

Gmelina seed oil (GSO), reagents, glass wares, viscometer, magnetic hot plate, water bath, soxhlet extractor, engine test bed, gas analyzer etc.

B Production of gmelina seed oil biodiesel or gmelina seed oil fatty acid methyl ester (GSO biodiesel or GSOFAME) by transesterification

Gmelina seed oil (GSO) was prepare by solvent extaction of the seeds. The extracted oil with excess free fatty acid was esterified using methanol and sulphuric acid. The pretreated oil was then transesterified using methanol and sodium hydroxide catalyst. Onto the side arms of a three necked round bottomed flask which served as the reactor, were fitted a thermometer and a receiver, and the central arm was fitted with a condenser. The amount of oil specified for the process was introduced into the flask and heated to the required temperature of the reaction by an electromagnetic hot plate. A mixture of sodium hydroxide in methanol of specified quantity required for the reaction was added onto the flask. The hot plate stirrer was switched on after setting the stirring speed to the value required for the reaction. During heating, the flask content was thoroughly stirred and refluxed. At the end of transesterification, the flask content was poured into a separating funnel and allowed to settle for a day, where it separated into upper biodiesel layer and the lower glycerol layer. The two layers were tapped off separately, the glycerol layer first followed by the biodiesel layer. As the biodiesel layer may contain some traces of sodium hydroxide and glycerol, they are removed by wet washing. The washed biodiesel was then dried on a laboratory hot plate at 105^0C to remove all traces of moisture remaining in it.

E Determination of the fuel properties of GSO biodiesel produced

The properties of the GSO biodiesel fuel were characterized based on ASTM standards. The biodiesel properties characterized for include density, viscosity, iodine value, saponification value, cetane number, acid value, free fatty acid, calorific value, flash point etc.

F Engine performance evaluation test

The engine performance evaluation test of the GSOFAME and blends was carried out on a Perkins 4:108 diesel engines mounted on a steady state engine test bed as in plate1. The engine is a four cylinder, water-cooled, naturally aspirated, 4-stroke CI engine. The engine specification is as given in Table 1. The experiment was conducted with no. 2 diesel fuel, GSOFAME and their blends consisting of the following percentages by volume of GSOFAME, 0%, 20%, 40%, 60%, 80% and 100% denoted by B0, B20, B40, B60, B80 and B100 respectively at constant load and varied speed of 1000-2000rpm. The engine performance and emission test was also carried out at constant speed and varied load of 20-100kg using the B0-B100 blends. A short test run on the engine was done in order to ensure that all essential accessories were in working order before the actual test.

(a) Engine performance test at varying speed and constant load

100cm^3 of the fuel blend tested was run into the fuel chamber. The engine was started and kept at maximum load of 100kg.The engine speed in rpm was measured using the tachnometer attached to the dynamometer and was initially kept at low value of 1000rpm. The engine torque was taken. The time taken to exhaust the 100cm^3 of the fuel blend was read using a stopwatch. The manometer reading and the exhaust temperature reading were taken. The above procedure was repeated for higher speed values of 1200rpm, 1400rpm, 1600rpm, 1800rpm and 2000rpm.

(b) Engine performance and emission test at varying load and constant speed

Here, the engine was started after running into the fuel chamber 100cm^3 of the fuel blend tested. The engine was kept at a constant speed of 1900 rpm, and loaded 20kg. The necessary readings as in procedure (a) were taken including the data of exhaust emission. The gas emissions of nitrogen oxides (NOx), carbon monoxide (CO), and hydrocarbons (HC) were measured from the end of the exhaust pipe of the engine using portable digital gas analyzer (Testo XL 450). After taking the readings at 20kg load, the load on the engine was varied using dynamometer loading wheel. The above procedure was then repeated in turn for higher load values of 40kg, 60kg, 80kg and 100kg.

Plate 1: Perkin 4:108 diesel engine mounted on Steady state engine test bed at UNN Nsuka

Table 1: Engine specifications

Components	Values
ENGINE	
Type	Perkins 4:108
Bore	79.735mm
Stroke	88.9mm
Swept volume	1.76litres/cycle
Compression ratio	22:1
Maximum BHP	38
Maximum speed	3000rpm
Number of cylinder head	4
Diameter of exhaust	$1^1/_2{}''$
Length of exhaust pipe	36"31'
DYNAMOMETER	
Capacity	112kw/150hp
Maximum speed	7500rpm
KW	(N_mx rev/min)/9549.305
FUEL GUAGE	
Capacity	50-100 cc
AIR BOX	
Orifice size	58.86mm
Coefficient of discharge	0.6

Source: Department of Mechanical Engineering, University of Nigeria Nsuka

III. RESULTS AND DISCUSSION

A. Fuel properties of GSO biodiesel

The fuel properties of GSOFAME produced are as summarized in table 2. The fuel density and kinematic viscosity of 874kgm^{-3} and 4.794mm^{2}s^{-1} at 40^{0}C respectively are within the ASTM standard limit and lower than that of the oil from which it was produced. High kinematic viscosity is undesirable in biodiesel as it leads to poor atomization and incomplete combustion, coking of injector tips and hence depletion of engine power [14]. In like manner, very low viscosity fuel is undesirable as it results in very subtle spray that enters the combustion cylinder with leakages at the piston clearance and thus create fuel rich zone that is prone to sooth formation [15], [16]. The flash point of GSOFAME obtained as 154^{0}C is within the ASTM limit as this is higher than the minimum value stipulated as 130^{0}C by the organization. The GSO biodiesel cetane number of 64.2 is indicative of good ignition quality of the fuel as the ASTM lower limit for the property is 47. The calorific value of 38.33MJ/Kg is close to that of diesel of value 44.34MJ/Kg. The cloud point and pour point of 5^{0}C and 3^{0}C are on the high range which may result in handling and storage problems during cold weather. However, the use of cloud point and pour point depressants would lessen the problem.

Table 2: Fuel properties of GSO biodiesel with testing method

Property	Unit	GSOFAME	Test Method
Density	Kgm^{-3}	874	D93
Kinematic Viscosity	mm^{2}s^{-1} at 40^{0}C	4.795	D445
Cetane number		64.2	D613
Flash point	^{0}C	178	D93
Cloud point	^{0}C	5	D2500
Pour point	^{0}C	3	D2500
Acid value	mgKOH/g	0.24	D664
Calorific value	MJ/Kg	38.33	

B. Engine performance evaluation of diesel, GSOFAME and the blends

The data generated from the engine performance test, namely volume of fuel used, time, mass flow rate, torque etc and those of characteristics of the biodiesel and diesel were used for calculation of the engine performance evaluation characteristics namely, brake specific fuel consumption (BSFC), brake thermal efficiency (BTE) and brake power (BP). These performance evaluation characteristics for the biodiesel, diesel and their blends were correlated by their plots with, engine speed and with engine load in order to discern their effects on engine speed and on engine load. The correlation plots for biodiesel and the blends were compared with that of diesel in order to evaluate the performance and suitability of the biodiesel and the blends as a suitable compression ignition engine fuel.

(a)Calculations on engine performance test

(i) Volume flow rate of fuel, V_f (m^3/s) =V/t
Where V= volume of fuel (m^3) and t = time(s)
(ii) Mass flow rate of fuel M_f,(kg/s) = $\rho_f V_f$
(iii) Brake power, BP (KW) = TxN/9549.30
Where T=torque (Nm), N =engine speed (rpm), ρ_f = density of fuel (Kg/m^3)
(iv) Brake thermal efficiency n_{BT}(%) = BP/M_f x44200
(v) Brake specific fuel consumption, BSFC (Kg/KWh) = 3600M_f/BP

(b)Effect of engine speed on engine performance evaluation characteristics

(i) Effect of engine speed on brake specific fuel consumption (BSFC) for diesel, GSOFAME and the blends

An engine of low BSFC use less amount of fuel to produce equal amount of work as one rated higher and as such low BSFCis preferred to higher one. The effect of engine speed on BSFC is shown in figure 1. From the figure, it could be observed that BSFC decreased with increase in engine speed and attained minimum value at an engine speed of 1600rpm for B0-B40 and 1800rpm for B60-B100 and then starts increasing with increase in speed. This is corroborated with the works of [17] who reported that minimum BSFC occurred at 1600rpm using macadamioa oil biodiesel. The decrease of BSFC with engine speed could be attributed to the fact that initially, the engine speed was relatively low and therefore the engine and fuel temperatures as well were low and as such the viscosity and lubricity were stably high resulting to high torque and thermal efficiency of the engine. The later increase in BSFC with engine speed stems from the fact that at higher speed, the engine and fuel temperature soared resulting in the reduction of the viscosity and lubricityof the fuel. Consequently, the torque and thermal efficiency of the engine decreases resting in higher BSFC. Again from figure 1, it could be observed that at specific engine speed, the BSFC increases with increase in biodiesel fraction in the blend. This agrees with the findings of [18]-[23] who reported that fuel consumption of an engine fueled with biodiesel is higher as more of the fuel is required to compensate for the low heating value of biodiesel. It could then be seen that B100 is of highest BSFC value while B0 has the least value. The B0 and B20 BSFC approximate each other because of their equivalent heating values.

(ii) Effect of engine speed on brake thermal efficiency for diesel, GSOFAME and blends

Figure 2 shows the effect of engine speed on brake thermal efficiency of a diesel engine fueled with diesel, GSOFAME and the blends. The figure shows that BTE increased with increase in engine speed at full load and peaked at 1600rpm for B0-B40 and 1800rpm for B60-B100 and then decreased with increase in speed, Increased BTE with engine speed initially occurred as increase in speed resulted to increased torque and thermal efficiency of the engine. At higher speed in excess of 1600rpm or 1800rpm as the case may be more amount of fuel is injected into the combustion cylinder per cycle. As a result of the high engine speed, the fuel will not have sufficient time for complete combustion. This reduces the engine efficiency [24]. It could also be observed from figure 2 that the thermal efficiency of B0 and B20 are very close as a result of their equivalent heating values. However, the BTE of B20 was superiority to that of diesel as B20 combined the high lubricity of its biodiesel content and the high heating value of its high diesel content to give improved BTE. Again from the figure, it is discernible that at specific engine speed, brake thermal efficiency decreased with increase in biodiesel fraction in the blends ostensibly as a result of low calorific value of biodiesel compared with diesel. Thus B0 has the highest BTH while B100 has the least value.

(iii) Effect of engine speed on brake power for diesel, GSOFAME and blends

Figure 3 shows that the BP of the diesel, GSOFAME and the blends increase with increase engine speed and peaked at 1600rpm for B0-B100 and then starts decreasing with increase in speed. The increase in BP with engine speed initially observed before peaking at 1600rpm results because at the relatively lower speed the torque increased with increase in speed coupled with the high lubricity at such speed. At higher speed in excess of 1600rpm, the torque as well as the lubricity of the fuel reduced with increase in speed resulting in the reduction of engine BP. This is in agreement with the findings of [16], [18], [19], [25], and [26] who reported that engine power decreased with increase in biodiesel fraction in the blend.

(c)Effect of engine load on engine performance evaluation characteristics

(i) Effect of engine load on brake specific fuel consumption for diesel, GSOFAME and the blends

Figure 4 shows the effect of engine load on BSFC of the fuels. From the figure, it is discernible that the BSFC decreased with increase in engine load and attained minimum value for all the blends at 70% of the maximum load or 70kg and then started to increase with increase in load. This is in conformity with the findings of the researchers [27] and [28] who tested the engine performance of Karanja and Jatropher oil biodiesel respectively. Researchers [29]-[32] reported that high amount of biodiesel is used for fueling diesel engine as the excess amount compensates for its lower heating value. The figure also revealed that at specific engine load, BSFC of the blends increased with increase in biodiesel fraction with B100 having the highest BSFC and B0 having the least. However the BSFC of B0 and B20 approximate each other owing to their closeness of energy content.

(ii) Effect of engine load on brake thermal efficiency of diesel, GSOFAM and the blends

As revealed in figure 5, brake thermal efficiency increased with increase in engine load and peaked at 70% of the load and then started decreasing as the load increased. This is corroborated with the findings of [27], [28]. From the figure it could also be observed that at specific engine load, brake thermal efficiency decreases with increase in biodiesl fraction with B100 having the least BTH and B0 the highest value. The BTH of B0 and B20 are very close as a result of their equivalent heating value. However from the figure it is revealed that the BTH of B20 is superior to that of B0 due to the combination of high thermal efficiency of the diesel content of B20 and the high lubricity emanating from the biodiesel content.

(iii) Effect of engine load on brake power for diesel, GSOFAME and the blends

As shown in figure 6 the engine load increased with increase in brake power and peaked at 70% of the load and then started decreasing with increase in load. Again this conforms to the findings of [27], [28]. From the figure it is clearly seen that at specific engine load, the BP increased with increase in engine load and attained maximum value at 70% load when it started decreasing with increase in load. The increase in BP before attaining the maximum value can be explained by the increase in engine torque and brake thermal efficiency resulting from increase in load. However on exceeding the 70% maximum load, the torque and thermal efficiency decreased as a result of high engine and fuel temperature emanating from the higher speed, which thus decreases the brake power. Also at specific engine load, the BP decreased with increase in biodiesel fraction with B100 having the least BP and B0 the highest. These findings are in agreement with those of [33], [34] that reported a decrease in engine power with increase of amount of biodiesel.

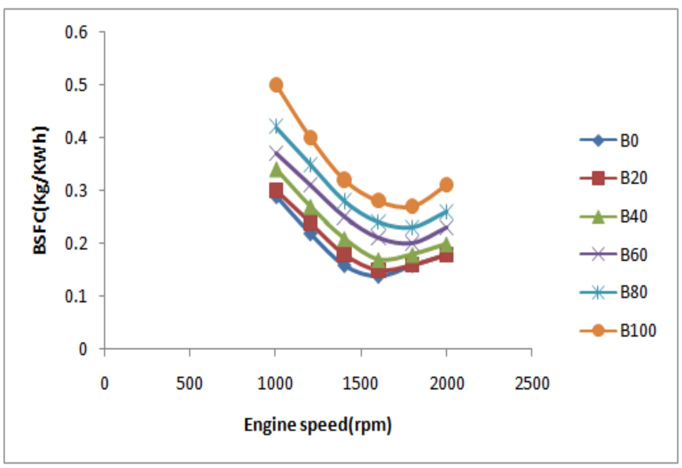

Figure 1: Effect engine speed on BSFC for diesel, GSOFAME and blends

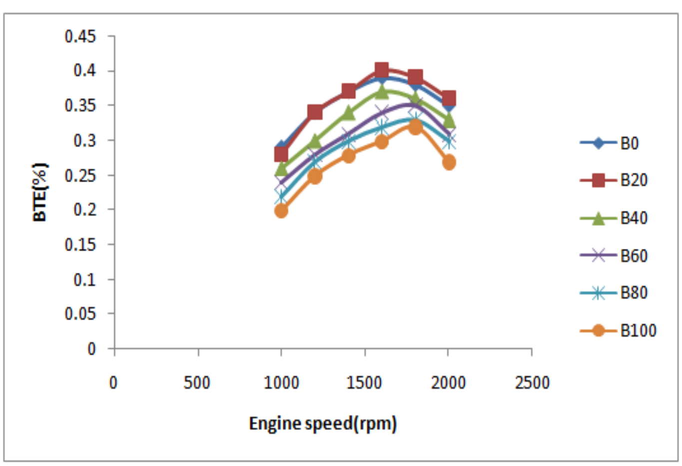

Figure 2: Effect of engine speed on BTE for diesel, GSOFAME and blends

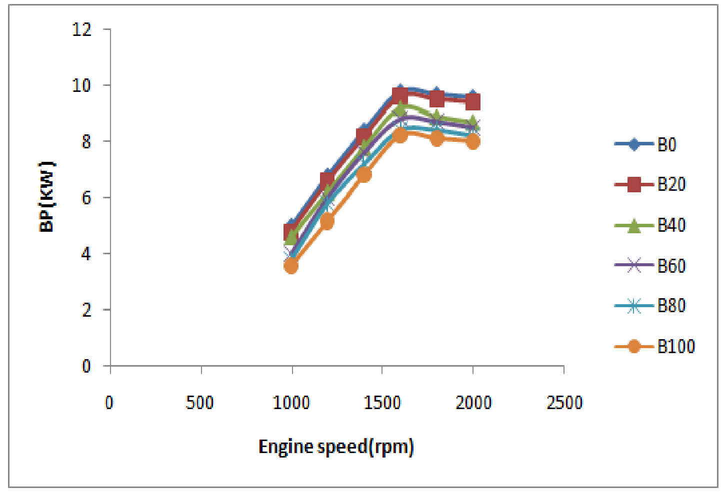

Figure 3: Effect of engine speed on brake power for diesel, GSOFAME and the blends

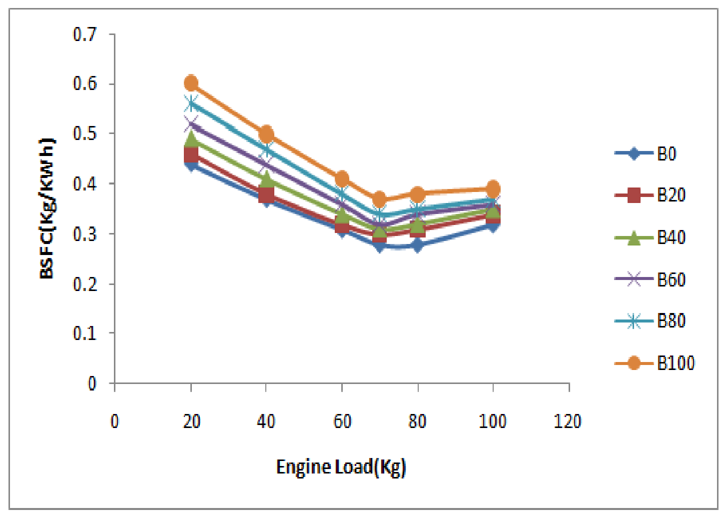

Figure 4: Effect of engine load on brake specific fuel consumption for diesel, GSOFAME and their blends

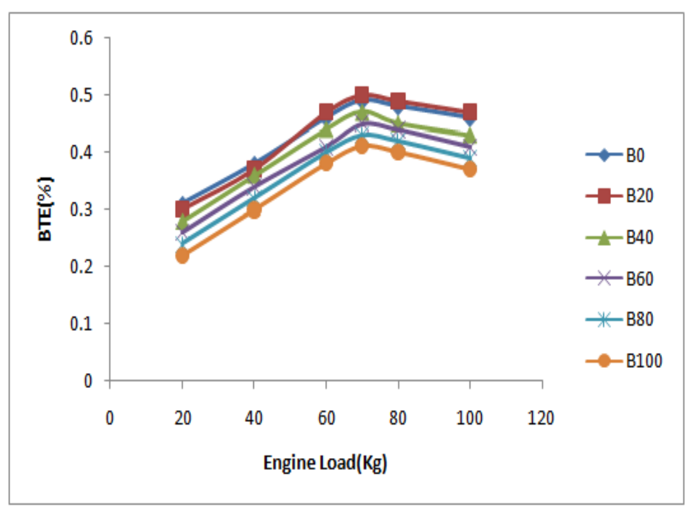

Figure 5: Effect of engine load on BTE for diesel, GSOFAME and the blends

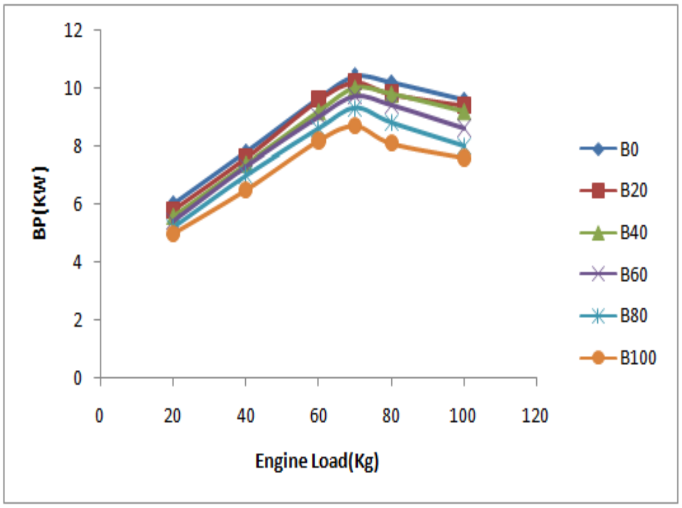

Figure 6: Effect of engine load on bake power for diesel, GSOFAME and the blends

(d)Effect of engine load on CO, HC and NOx emission of diesel, GSOFAME and the blends

(i)Effect of engine load on CO and HC emission of the blends

Figures 7 and 8 showed the effect of engine load on CO and HC emission respectively for diesel, GSOFAME and the blends. From the figures it could be observed that CO and HC emission increased with increase in engine load. The increase in emission results from decreased air-fuel ratio resulting from increase in load which gave rise to incomplete burning of the fuels. From figures 7 and 8 respectively it could be observed that CO and HC emissions decreased with increase in biodiesel fraction in the blend. The researchers (35], [36] have reported a reduction in CO and HC emission when a diesel engine is fueled with biodiesel instead of diesel. This shows that the use of biodiesel lowers the CO and HC emission. This could be explained from the point of view of oxygen content and low carbon to hydrogen ratio of biodiesel. The oxygen content of biodiesel increased the vaporization and atomization of biodiesel and hence the complete combustion leaving low amount of CO and HC in the combustion product as compared to diesel fuel [37]. The low carbon to hydrogen content of biodiesel presents less carbon to be burnt which gave rise to low CO and HC in the combustion product.

(ii)Effect of engine load on NOx emission of diesel, GSOFAME and the blends

Figure 9 shows the effect of engine load on NOx emission for the fuels. From the figure it could be observed that NOx emission increased with increase in engine load. This could be explained by the fact that increase in engine load reduce the air-fuel ratio resulting in incomplete combustion of the nitrogen components of the biodiesel, thus emitting the oxides of nitrogen or NOx. From the figure, it is also discernible that at specific engine load, NOx emission increases with increase in biodiesel fraction. This is in conformity with the findings of the researcher [35] and [36].

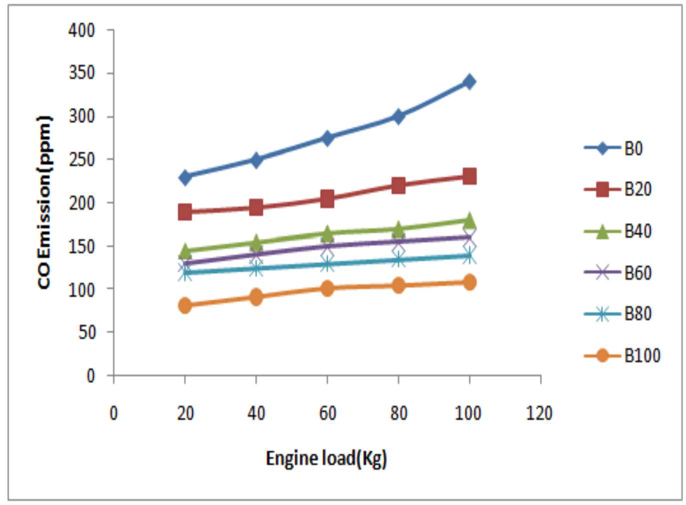

Figure 7: Effect of engine load on CO emission for diesel, GSOFAME and their blends

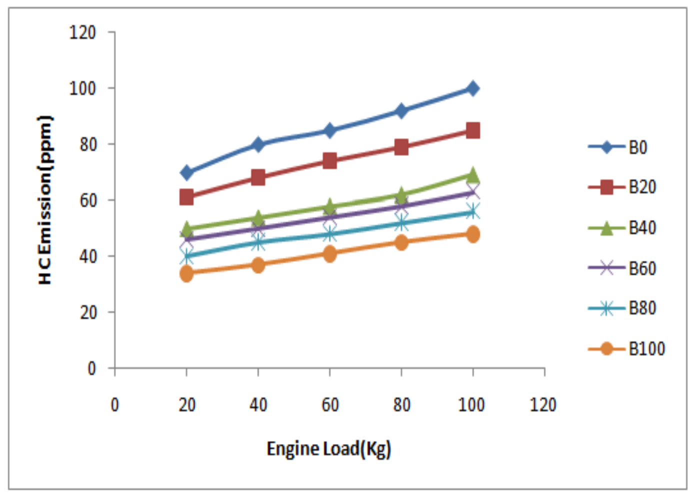

Figure 8: Effect of engine load on HC emission for diesel, GSOFAME and their blends

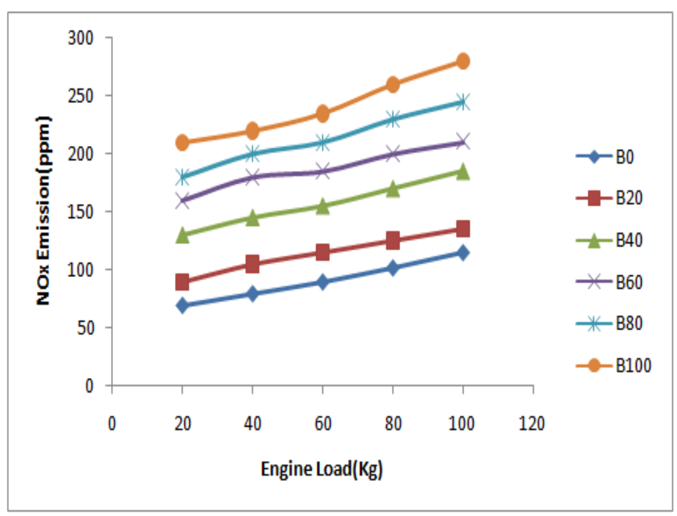

Figure 9: Effect of engine load on NOx emission for diesel, GSOFAME and their blends

IV. CONCLUSION

Comparison of the engine performance evaluation parameters of, BSFC, BTE and BP of GSOFAME and blends with diesels' showed that they are equivalent to diesels'. The performance evaluation characteristics of B20 and of blends of less biodiesel content are equivalent to that of diesel and sometimes proved to be superior to diesel as exhibited by B20 thermal efficiency. From the results, it is evident hat B20 and blends with less biodiesel content could be conveniently used as compression ignition engine fuel without modification of the engine. The low CO and HC emission from gmelina seed oil biodiesel shows that the biodiesel should have no adverse impact on environmental pollution and therefore serves as environmentally friendly fuel.

REFERENCES

[1]. H. Fukuda, A. Kondo, & H. Noda, (2001). "Biodiesel fuel production by transesterification of oils". *Bioscience, Bioengineering Journal*, 92, 405-416.

[2]. A. Demirbas, (2009). "Progress and recent trends in biodiesel fuels". *Energy Conversion and Management* 50, 14-34.

[3]. D.Y.C.Leung, & Y. Guo, (2010). "Transesterification of meat and used frying oil: Optimizationfor biodiesel producton". Fuel *Process Technology*, 87. 883-890.

[4]. N.A.N Younis, S.K. Kamarudin, and Z. Yaakub, (2011). "Overview of the current trends in biodiesel production". Energy Conversion and Management, 52(7), 2741-2751.

[5]. L. Attanatho, S. Magmee, P. Jenvanitpanjakul, (2004). "Factors affecting the synthesis of biodiesel from crude palmkernel oil". *The Joint International Conference on Energy and Environment* (SSE), Hua Hin, Thailand, 1-3 Deember 2004.

[6]. S.D. Romano, P.A. Sorichetti (2011). "Dielectric Spectroscopy in biodiesel production And characterization". *Green Energy and Technology*. VIII 104p.

[7]. E. Mensah, G.Y. Obeng, E. Aniwi, (2013), "Engine Performance Evaluation Using Biodiesel From Waste Palm Kernel Oil, Mixed WVO And Diesel Fuel".The *International Journal of Engine ering And Sciences*, 2(90), pp19-25.

[8]. N.A. Musa, G.M. Teran, and S.A.Yaman (2016). "Performance Evaluation of a Diesel Engine Run on Biodiesel Produced from Coconut Oil and Its Blends". Advances in Research 6(4) 1-6.

[9]. J.C.Umeuzuegbu, (2020). "Impact of Used Soya Oil Biodiesel on the Performance and Emission of Diesel Engine". *Journal of Multidiciplinary Engineering Science and Technology*, 7(9), 12704-12716.

[10]. N. Kumar, S. Soni, D. Sharma, A. Srivastava, (2016). 'Performance Evaluation and Emission Analysis of Variable CompressionRatio Direct Injection Diesel Engine". *MATTER: International Journal of Science and Technology*, 2(2), 32-47.

[11]. S.I. Murtdh, J.K.Hayder, (2018). "The Effect of Using Water Corn Oil on Compression Ignition Engine Performance". *International Journal of Applied Engineering Research*, 13(6), 3966-3974.

[12]. M. Saravanakumar, M. Prabhabar, V. Manikandan,.,MP. Sajin , K. Gangadharan, (2019). "Performance Characteristics of VCR Engine Using Lemon Grass Oil and Methanol Mixed With Diesel". *International Journal of Engineering and Advanced Technology*, 9(2) 3461-3465

[13]. Y. Husan, S. Hamit, L.A. Yacup, "Comprehensive Study on Engine Performance and Emission of Biodiesel and JP-8 aviation Fuel in a Direct Injection Diesel Engine". *Indian Journal of Engineering and Material Sciences*, 22, 438-444.

[14]. M.M.P. Endah, M. Rachimoellah, S. Nidya, & P. Ferdy, (2012). "Biodiesel production from kapok seed oil (*Ceiba pentandra*) through the transesterification process by using Cao as catalyst", *International Research Journal*, 12(2),3-7.

[15]. D.P. Prafulla, G.G. Veera, K.R. Harvind, M. Tapaswy, & D. "Shuguang (2012). Biodiesel Production from waste cooking oil using sulfuric acid and microwave irradiation processes". *Journal of Environmental Protection*, 3, 111 -117.

[16]. S. Murillo, J.L. Miguez, J. Porteiro, E. Granada, J.C. Moran, "Performance and exhaust emission in the use of biodiesel in outboard diesel engines". Fuels 2007:86:1

[17]. Azad, M.R.,Abul, K. & Masud K.M. (2016). Production of Biodiesel using homogeneous alkali catalyst and its emission effect. *1st International Conference on Energy and Power*, ICEP,vol.12. Sydney, Australia.

[18]. A.N. Ozsezen, M. Canakci, A. Turkcan, C. Sayin, "Performance and combustion characteristics of a DI diesel engine fueled with waste palm oil and canola oil methyl esters". *Fuel* 2009:88:629-36.

[19]. M. Karabectas, "The effects of turbocharger on the performance and exhaust emission of diesel engine fueled with biodiesel". *Renewable Energy* 2009:34: 989-93.

[20]. Z. Utlu, M.S. Kocak, "The effect of biodiesel fuel obtained from waste frying oil on direct injection diesel engine performance and exhaust emissions". *Renewable Energy*2008:33: 1938-41.

[21]. E.Buyukkaya, "Effects of biodiesel on DI diesel engine performance , emission and Combustion characteristics". *Fuel* 2010: 3099—105.

[22]. S-H. Choi, Y. Oh, "The emission effect by the use of biodiesel fuel". *Int Mod Phys* 2006:20:4481-6.

[23]. N. Fernando, SP. Anthonio, RT Jorge, "Technical physibility assessment of oleic sunflower Methyl ester utilization in diesel bus engines". *Energy conversion Management* 2003: 44:2657-78.

[24]. G. Labeckas, & S. Slavinskas, (2006). "The effect of rapeseed oil methyl ester on direct injection diesel engine performance and exhaust emissions". *Energy Conversion Management*, 47, 1954-1967.

[25]. A.C. Hansen, M.R. Gratton, W. Yuan, “Diesel engine performance and NOx emissions from oxygenated biofuels and blends with diesel fuel”. *Trans ASABE* 2006:49:589-95.
[26]. J.F. Reyes, M.A. Sepdiveda, “PM-10 emission and power of diesel engine fueled with crude and refined biodiesel from salmon oil”. *Fuel* 2006: 85: 1714-9.
[27]. N. Stalin, H.J. Prabhu, (2007). “Performance Test of IC Engine Using Karanja Biodiesel Blending with Diesel”. *ARPN Journal of Engineering and Applied Sciences*, 2(3), 12-14.
[28]. S. Sharma, R.Singh, M. Mishra, K.G. Mitra, and K Gangwar,”Perfoemence and Emission Analysis of Diesel Engine Using Biodiesel and Preheated Jatropher oil”. *International JournalOf Current Research and Academic Review*, 2(6): 229-239.
[29]. B-F. Lin, J-H. Huang, D-Y. Huang, “Experimental Study of the effect of vegitable oil Methyl ester on DI diesel engine performance characteristics and pollutant emissions”. *Fuel* 2009:88:1779-85.
[30]. B. Gbobadian, H. Rahimi, AM. Nikbakht, G. Najafi, TF. Yusaf. “Diesel engine Performance and ehhaust emission analysisusing waste cooking biodiesel fuelwith an artificial neural network”. Renewable Energy 2009:34:976-82.
[31]. D-H Qi, L.M. Geng, H. Cheng, YZH. Bian, XCH. Ren, “Combustion and performance evaluation of a diesel engine fueled with biodiesel produced from soybean crude oil”. Renewable Energy 2009:34:2706-13.
[32]. M. Lapuerta, O. Armas &J.R. Fernandez, (2008). “Effect of Biodiesel Fuels on diesel engine Emissions”. *Progress in Energy and Combustion Science*, 34, 198-223.
[33]. C.Kaplan, R. Arsian, A. Surmen, “Performance characteristics of sunflower methyl ester as biodiesel”. Energy source part A 2006: 28: 751-5.
[34]. J.F. Reyes, M.A. Sepdiveda, “PM-10 emission and power of diesel engine fueled with crude and refined biodiesel from salmon oil”. Fuel 2006: 85: 1714-9.
[35]. H. Aydin, H. Bayindir, “Performance and emission analysis of cottonseed oil methyl ester in a diesel engine”. Renewable energy 2010:35:588-92.
[36]. A.N. Ozsezen, M. Canakci, A. Turkcan, C. Sayin, “Performance and combustion characteristics of a DI diesel engine fueled with waste palm oil and canola oil methyl esters”. Fuel 2009:88:629-36.
[37]. M. Karabectas, “The effects of turbocharger on the performance and exhaust emission of diesel engine fuelled biodiesel”. Renewable Energy 2009:34: 989-93.
[38]. H.C. Ong, H.H. Masjuki. T.M.I. Mahlia, A.S. Silitonga, W.T. Chong. & T.Yusaf, (2014). “Engine performance and emissions using *Jatropha curcas, Ceiba pentandra* and *Calophyllum inophyllum* biodiesel in a CI diesel engine”. *Energy*, 69,427- 45.