A comparative performance and emission analysis of blended groundnut oil and mineral oil based lubricants using a spark ignition engine

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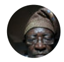

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A Comparative Performance and Emission Analysis of Blended Groundnut Oil and Mineral Oil Based Lubricants Using a Spark Ignition Engine.

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ABSTRACT

This paper presents the performance and emission behaviour of a spark ignition engine run on groundnut oil blended lubricants. However, for the purpose of comparism, benchmark tests were carried out on multigrade and monograde motor oils. A 5.0 h.p engine test-bed incorporated with an A.C dynamometer and flue gas analyzer was used to conduct the tests. At maximum engine speed, the groundnut oil blended lubricants generated an exhaust temperature of 6.02% higher than multigrade oil, and 6.26% higher than monograde oil. The brake power was 12.70% and 10.94% higher than the monograde and multigrade oils. In terms of fuel economy, the monograde and groundnut oil blended lubricants are 7.50% and 2.18% higher than multigrade oil respectively. It is shown that as the proportion of viscosity modifier in the oil sample increases, exhaust temperature, brake power, brake mean effective pressure (b.m.ep) also increases, while the specific fuel consumption diminishes. At various speeds, CO_2 level emitted by the use of groundnut oil blended lubricants was observed to be higher than it was the case for multigrade and monograde oils. In the light of the fast depleting fossil fuel reserve in Nigeria, this work has demonstrated the feasibility of using groundnut oil blends as lubricant substitutes in spark ignition engines.

Keywords: Groundnut oil, motor oils, exhaust temperature, brake power, specific fuel consumption, and exhaust emission, Nigeria

1. INTRODUCTION.

Tropical seed crops such as Hausa groundnut (*Macrotyloma geocarxpum*) possess enormous industrial and export potentials, because their oils are used for a variety of foods and *Oleo*-chemical products in Nigeria (RMRDC, 1996). In this regards also seed oils have been used as lubricants in their natural forms, their excellent lubricity, high viscosity index, flash point and biodegradability make them more superior to mineral oils (Lou, 2001). In recent times, there is renewed research interest in the use of seed oils as alternative to mineral oil based lubricants. This is because of their cost-offsetting advantages such as; longer drain intervals, cleaner running engines, relatively higher viscosity index; pressure at hot idle, less environmental problems and good lubricity (Goering, 1992; Pickering and Owens, 1994). On a comparative note, biobased lubricants and biodiesels share a common origin. They are both derived from agricultural feedstock. It is important to note that oiliness and viscosity of seed oils are essential for boundary and hydrodynamic lubrication between contacting metallic surfaces in relative motion. While on the other hand, it was also reported that viscosity of seed oil is a constraint limiting its application as diesel fuel substitute. This is because it reduces fuel spray atomization and increases fuel spray penetration thereby increasing engine deposits and lubrication oil thickening in compression ignition engines (Sangha et. al 2004 and Alamu et. al., 2007) It has been established that palm oil could also be used as alternative fuel in compression ignition engines. Short term engine performance tests on vegetable oil produced impressive results. However, longer term test revealed some durability problems such as; injector coking, more engine deposits, ring sticking and thickening of the engine lubricant (Engelman et al., 1978; Sims et.al 1981; Barsic and Humke, 1981; Worgetter, 1981; Sapaun et.al 1996; and Ryan et.al 1984).

Crude vegetable oil consists mainly of triglycerides (95%), with other components, such as wax esters, pigment sterol, terpenes, phosphitide and sulphur components (Curruthers, 1992). The triglyceride consists of a glycerol (glycerine) backbone to which three fatty acid molecules are attached (Brown, 1987). The physico-chemical properties, composition of fatty acid and lubrication characteristics of the Nigerian runner variety of groundnut oil are presented in Table 1, 2 and 3 respectively. However, in view of the significant depletion in crude oil reserve due to indiscriminate extraction and lavish consumption of fossil fuel (Bhattacharya et al. 2006), this study was conducted to investigate the viability of groundnut oil as a lubricant alternative to mineral oil based lubricants in a single cylinder spark ignition engine.

Table 1. Physico- chemical properties of mineral oil lubricants and groundnut oil.

Properties	SAE 40	SAE 20w-50	Groundnut oil
Colour	Brownish	Light Brown	Light Brown
Refractive Index	1.490	1.482	1.472
Relative Density	0.89	0.88	0.92
Specific Viscosity	19.5	23.1	1.91
Kinematic Viscosity	149	170	24.7
Dynamic Viscosity	133.3	149.9	18.3
Acid Value	-	-	0.159
Iodine Value	-	-	96.1
Saponification Value	-	-	190.54
Ester Value	-	-	190.38
Peroxide Value	-	-	0.87

Table 2. Fatty acid composition (%) of groundnut oil

	-
Myristic	
Lauric	-
Palmitic	8.30
Stearic	3.10
Arachidic	2.40
Oleic	56.0
Palmitoleic	-
Linoleic	26.00
Bohenic	3.10
Lignoceric	1.10
Linolenic	-
Ricinoleic	-

Table 3. Lubrication characteristics of mineral based lubricants and groundnut oil.

Characteristics	Mineral oils		Groundnut oil
	SAE 40	SAE 20w-50	
Specific Gravity at 35^{o}C	0.895	0.890	0.918
Kinematic Viscosity at 40^{o}C	149	170	24.7
Kinematic Viscosity at 100^{o}C	4.5	18.5	2.0
Viscosity Index	95	122	238
Flash Point (^{o}C)	240	250	252
Pour Point (^{o}C)	-15	-27	-13
Heating Value(Mj/kg)	7.15	7.15	39.5
Ash Residue (%wt)	1.4	1.4	0.02

2. MATERIAL AND METHODS.

2.1 Material Preparation.

A given volume of groundnut oil was blended with oil treatment formulation manufactured by ABNA company, U.S.A to modify its viscosity in a 500ml beaker at B40 (i.e. 40 percent by volume with 60 percent by volume of viscosity modifier), B50, B60, B70, B80, B90 and B100 respectively. The mixtures were blended for 10 minutes in a 500ml beaker at room temperature and allowed to settle and observed for immiscibility and/or homogenous consistency. The viscometric property of the blended oils is presented in Table 4.

Table 4. Blending texture of oils mixed with viscosity modifier.

Oil type	Blended oil quality		
	Immiscible and unstable	Fairly miscible and consistent	Stable mixture with Homogenous texture
Groundnut Oil	B70-B95	B60-B65	B30-B55

2.2 Experimental Methods.

2.2.1 Engine performance test.

A 5.0 h.p single cylinder four-stroke JF 168 gasoline engine test bed with engine technical specifications presented in tables 5 and 6 was used for experimentation. The performance characteristics were studied between speeds of 2000rpm to 4000 rpm at an incremental speed of 500rpm adjusted after every one hour engine operation time. Benchmark tests were carried out with monograde and multigrade oil as engine lubricants.

Table 5. Technical specification of test engine.

Model	JF 168
Type	Single cylinder inclined at 25^{O}
Bore * Stroke	68mm x 45mm
Displacement	163ml
Ignition system	TCI Transistorized pointless)
Starting method.	Recoil starter
Max. Output/speed	4.0/4000 kW/rpm
Max. Torque	1.1/2500 kg-m/rpm
Net weight	15 Kg
Dimensions	330mm x 280mm x 390mm

Table 6. Dynamometric specification.

Type	HONDA Model R 1500
Maximum operating capacity	
A.C	220V, 50Hz, Single phase
D.C	12V, 8.3A
Maximum speed	4000rpm
Torque arm radius	130mm
Manufacturer	Honda motor, Tokyo, Japan

The test was repeated for the variety of groundnut oil blended lubricants at different throttle-settings for an experimental duration of 4 hours. The engine output torque and brake power were monitored from the dynamometer's torque arm, the flow meter and U- tube water manometer were used to measure the fuel flow rate and pressure across the air box orifice respectively, while the mercury –in-glass thermometer was used to measure the exhaust temperature.

2.2.2 Exhaust Gas Emission Analysis.

The test engine was allowed to run on monograde, multigrade oil and groundnut oil blended lubricants. Exhaust gas samples were trapped in a gas bladder at various engine speeds ranging from 2000rpm to 4000rpm at a speed incremental of 500rpm for each oil sample and analyzed with an Orsat apparatus .The agitation induced by raising and lowering the leveling flask cause the aqueous sodium hydroxide solution in the reagent bottle to absorb the carbon dioxide content present in the exhaust gas sample. As the leveling flask was placed to its original position and the rise in water level in the calibrated burette indicate the amount of carbon dioxide present in the exhaust gas. Furthermore, the knobs controlling the tubes filled with 210cm^3 solution of potassium pyrogallate, and ammonical solution of copper I chloride were opened consecutively, to allow the remaining oxygen and carbon monoxide gases to be selectively absorbed and their quantities measured from the rise in water level after agitation. Each procedure was repeated three times and their mean value recorded

3. RESULTS AND DISCUSSIONS.

The results of engine performance and exhaust emissions analysis are discussed as follows:

3.1 Engine Performance

Figure 1 shows that the brake power increases with engine speed for all tested oil. Table 7 also shows that at maximum engine power, SAE 40 monograde oil generated an engine exhaust temperature 6.02% higher than SAE 20w-50 multigrade oil. Similarly, groundnut oil blended lubricant is also 6.75% higher than SAE 20w-50. It was also observed that the exhaust temperature for both SAE 20w-50 and groundnut oil is very close and their difference is nearly 3^{o}C. The reason attributed for this phenomenon, is that multigrade oils are formulated for lower engine temperature, and the additives that goes into the multigrade oil makes it much more efficient in harsh environment of engine use. The groundnut oil's low output temperature is due to the existence of long chain fatty acids which forms monomolecular layers on metal surface. The fatty acids molecules are absorbed into the surface to improve their adhesiveness to metal surface and thereby reducing metal to metal contacts. Furthermore, Masjuki and Malegue, (1996) and Studt (1989) observed that the ease of adsorption of oil molecules increases with chain length and hence influences the lateral cohesion of the monolayer, to provide lubricity to moving parts thereby reducing friction and engine temperature. The results in table 7 demonstrates higher brake power output for groundnut oil by the order of 12.0% above SAE 40 and 10.9% above the multigrade oil. From the brake mean effective pressure (b.m.e.p.) curves for the tested oil samples in figure 2. The brake mean effective pressure was observed to rise slowly with increase in engine speed.

Table 7. Performance characteristics for blended groundnut oil at engine speed of 4000 rpm.

Performance characteristics	Manufacturer's specification	SAE 40	SAE20w-50	Groundnut oil blends
Exhaust Temperature. (^{O}C)	-	415	390	387
Torque (Nm)	17.6	11.54	9.7	11.02
Brake Power (kW)	4.0	4.0	4.07	4.57
Specific Fuel Consumption (g/kW-h)	-	92.37	85.92	87.8
Brake.Thermal Efficiency (%)	-	25.77	27.21	27.42
Air Fuel Ratio.	-	15.80	16.68	14.70
Generator Efficiency.(%)	-	4.80	24.02	20.01
Heat Loss.in Exhaust (kJ)	-	2362.76	2200.40	198.09

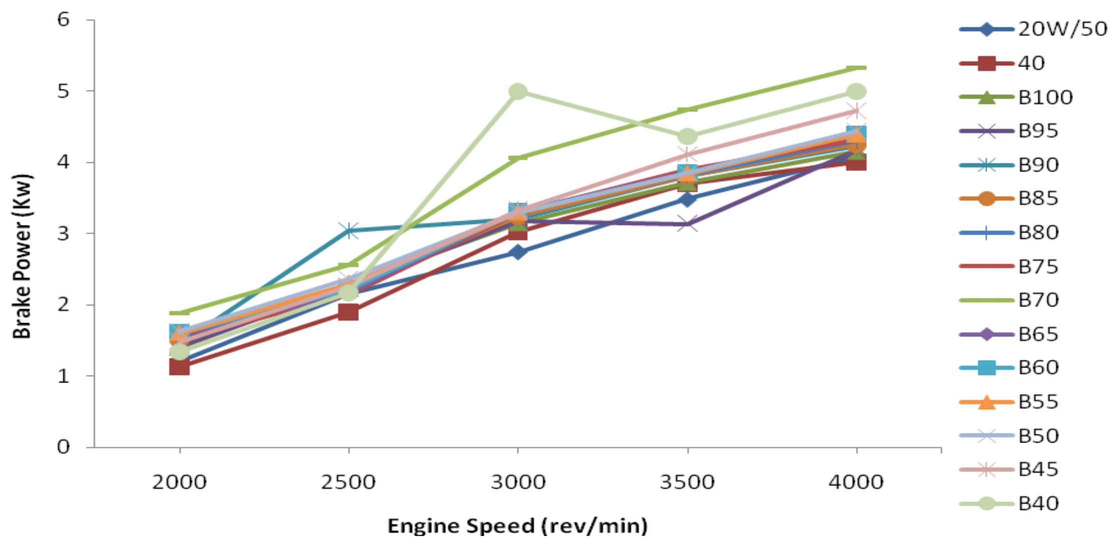

Figure 1. Effect of groundnut oil blend on brake power.

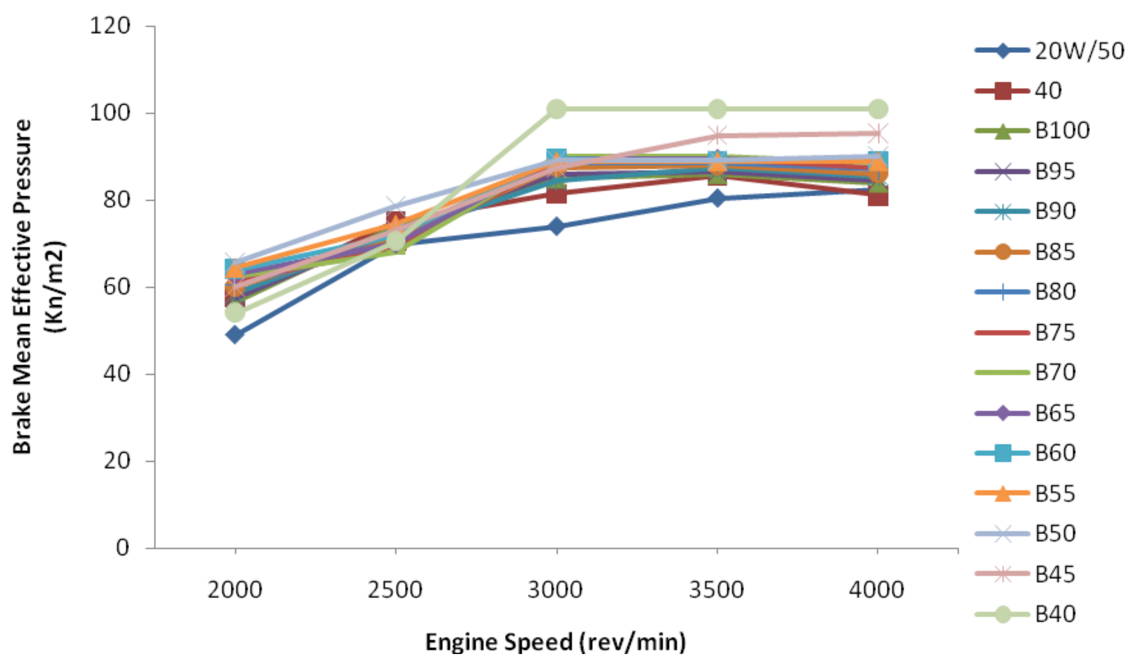

Figure 2. Effect of groundnut oil blend on brake mean effective pressure.

The fuel economy presented as specific fuel consumption (s.f.c) is illustrated in figure 3. The s.f.c is related to the quantity of fuel required to produce a given power output for a given length of time. Figure 3 shows that the groundnut oil blends have fuel economy at engine speed of 2000rpm to 2500rpm, while unblended groundnut oil (B100) showed highest s.f.c up to engine speed of 300rpm At speed greater than 3000rpm all the lubricants demonstrate low s.f.c. Table 7 shows that s.f.c values for SAE 40 monograde and groundnut oil blended lubricants are 7.50% and 2.19% higher than SAE 20w- 50 multigrade oil. Masjuki and Maleque, (1996) have found that, as the volumetric proportion of seed oils in lubricants increases, commensurate increase in brake specific fuel consumption occurred for higher specific gravity, higher viscosity and lower heating values of seed oils.

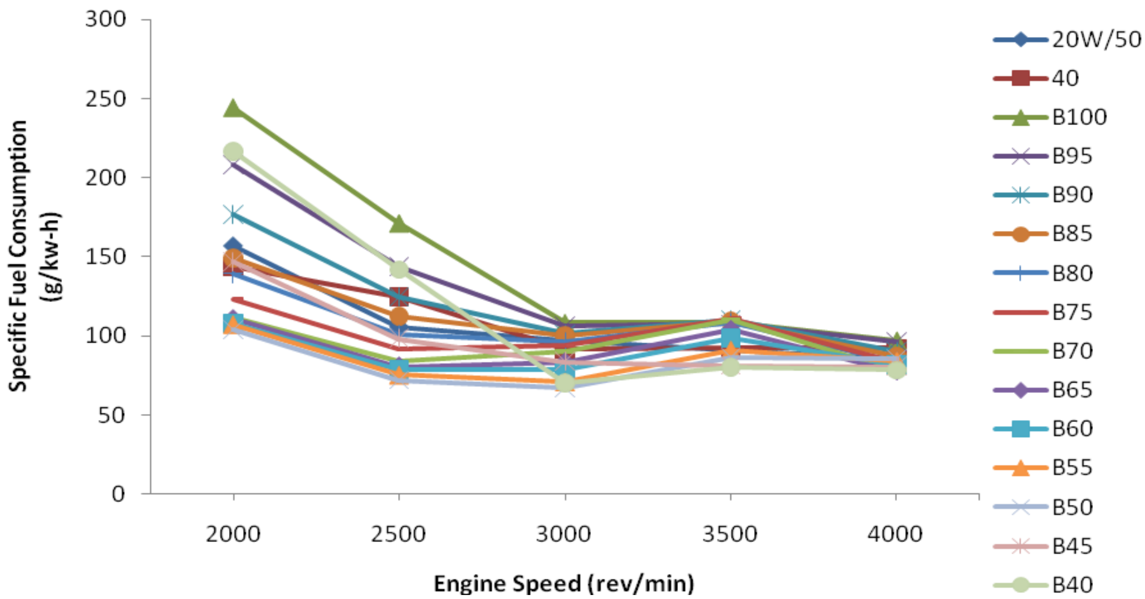

Figure 3. Effect of groundnut oil blend on specific fuel consumption.

Table 7 shows that in terms of brake thermal efficiency, the groundnut oil blended oils performed better than the multigrade and monograde oils. This could be attributed to lower heating value and combustion temperature of groundnut oil blended lubricants (Singh et al, 2007). Results for generator efficiency show that SAE 40 monograde oil is the best, and this may be due to its high viscosity. The heat loss in the exhaust is significantly higher for SAE 40 which goes to justify its high temperature behaviour recorded in the test.

Hence, this type of heat loss results in lower combustion efficiency and high hydrocarbon flue exhaust emissions in engines. Finally, the results indicate a lower overall engine performance when SAE 40 is used in comparison to other lubricants.

3.2 Exhaust Gas Emission

Figures 4, 5 and 6 present the results of CO_2, CO and unused oxygen emission levels for groundnut oil blended lubricant.

It could be seen that the CO_2 emission level are higher than SAE 40 and SAE 20w-50 oil benchmarks at 2000, 3000 and 4000rpm engine speeds. The CO2 levels for B100 to B40 groundnut oil blended lubricants varies from 6.60-1.20% , 7.80- 4.00% and 6.80-4.40% higher than SAE 20w-50, and 10.40-5.00%, 4.20-0.40% and 2.40% higher than SAE 40 at 2000rpm, 3000rpm, and 4000rpm engine speed respectively. The observable increase in CO_2 levels with respect to engine speed and blending proportion of oils is caused by higher oxidation of fuel, which ensured the release of more power. Sethi and Salariya, (2004) have also shown similar result in their work.

Figure 5 shows that when employing groundnut oil blends, the emission level of carbon monoxide is very negligible. This is in contrast to SAE 20w-50 and SAE 40 results that exhibited higher levels of CO emissions at lower engine speed of 1000rpm. However, at higher engine speeds of 3000rpm – 3500rpm, the CO emission levels for SAE 20w-50 is higher than SAE 40.

By varying the blending proportion of groundnut oil and viscosity modifier from B100 to B40 , it was observed that, the O_2 level dropped from 6.00-5.40% at 2000rpm, rose from 0-0.80% at 3000rpm and dropped further from 0.20-0.40% at 4000rpm lower than the unburnt O_2 level emitted as SAE 20w-50 oil was used. Furthermore, it was also observed that the O_2 levels dropped from 3.40-2.80% at 2000 rpm rose to 0.40% at 3000 rpm and decreased from 1.40 -1.00% at 4000 rpm than the O_2 levels emitted when SAE 40 motor was used.

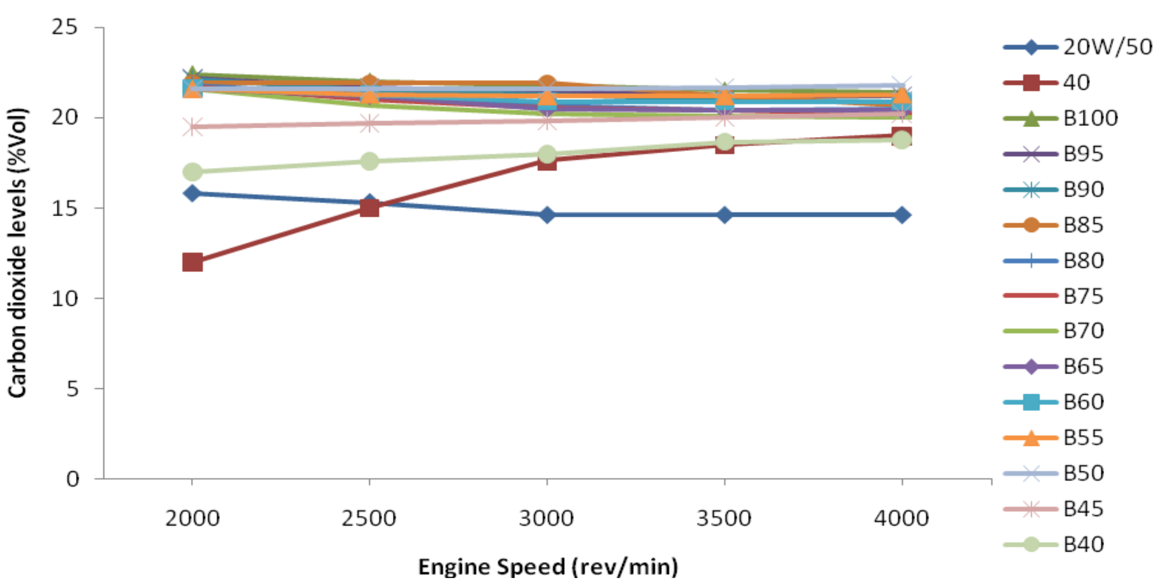

Figure 4. Effect of groundnut oil blends on carbon dioxide emission.

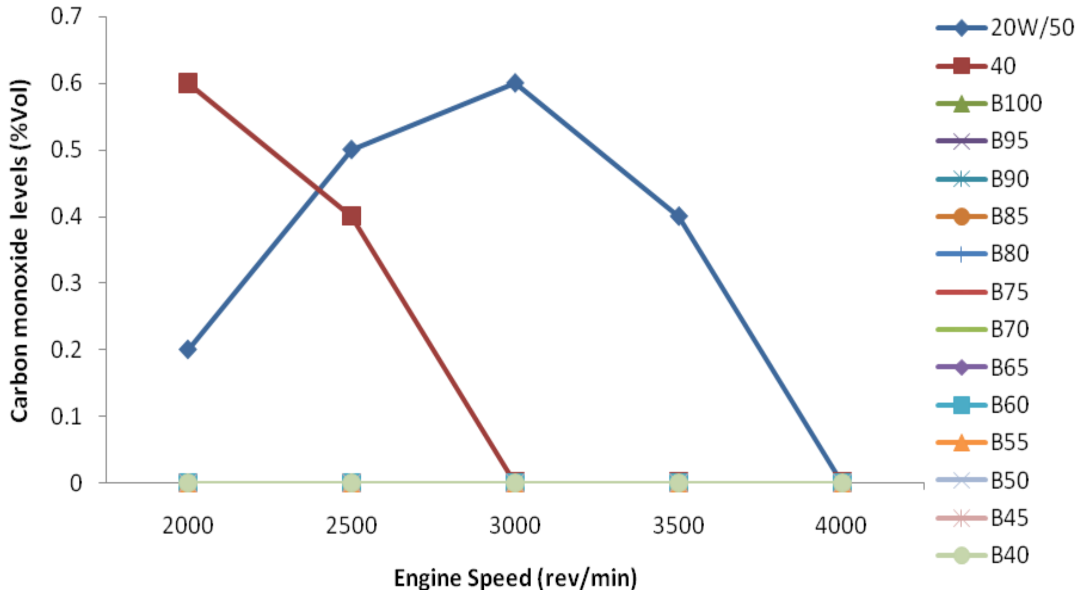

Figure 5. Effect of groundnut oil blends on carbon monoxide emission.

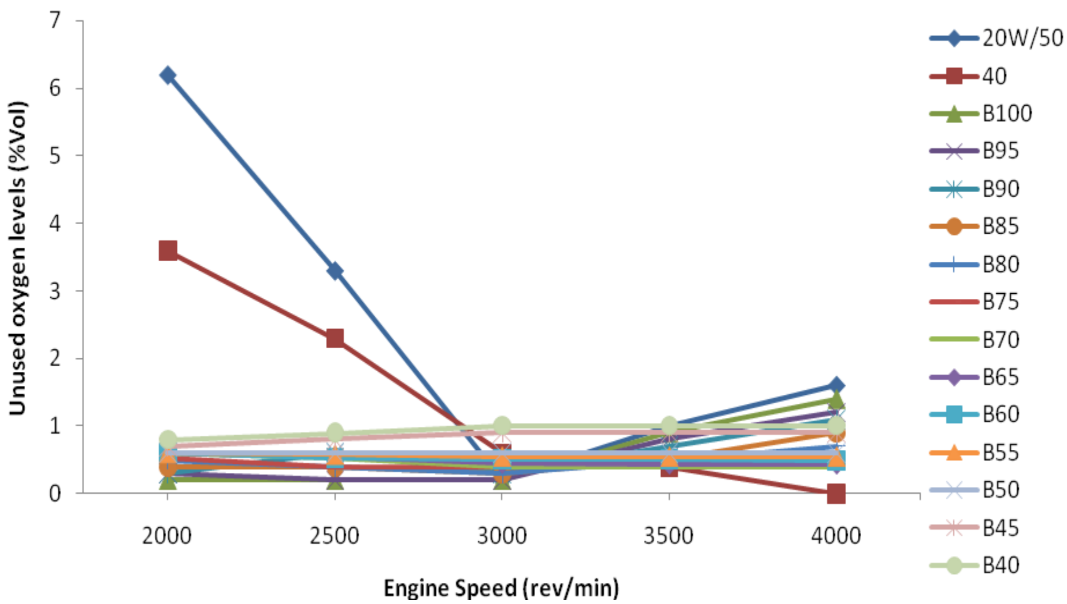

Figure 6. Effect of groundnut oil blends on unburnt oxygen emission.

4. CONCLUSION.

A comparative performance and emission analysis of blended groundnut oil and mineral oil based lubricants using a spark ignition engine was carried out. The results show that:

i. Groundnut oil blended lubricants presented a comparatively lower exhaust temperature than monograde and multigrade SAE oils.
ii. Groundnut oil blended lubricant demonstrated higher brake power, b.m.e.p than monograde and multigrade oils, but for the multigrade oil at the expense of higher fuel consumption.
iii. In terms of fuel economy, groundnut oil blended lubricants is slightly higher than multigrade oil and comparable to monograde oil.
iv. With viscosity modification, blended groundnut oil demonstrated a significant increase in exhaust temperature, brake power and b.m.e.p increase, and a decrease in specific fuel consumption, in comparison with mineral oil based lubricants.
v. CO_2 emission levels arising from groundnut oil blended lubricants are higher than emissions from monograde and multigrade oil.

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