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BIODIESEL FUELS FROM PALM OIL, PALM OIL METHYLESTER AND ESTER-DIESEL BLENDS

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ABSTRACT. Because of increasing cost and environmental pollution effects of fossil fuels, palm oil, its methylester and ester-diesel blends were analyzed comparatively with diesel for their fuel properties that will make them serve as alternatives to diesel in diesel engines. Equally, the samples were comparatively analyzed for their trace metal composition in relation to corrosion. Also the bond structure/stability of the samples in relation to diesel were monitored with a Fourier transform infrared spectrometer. Results confirmed that most methylester blends with diesel fell within the grade 2D while the oil, methylester and 90:10 blend fell into 4D grade diesel fuels. From bond structure/stability comparison, all the samples were stable at 28 °C and had similarity in structure with diesel. All samples are commercializable. The trace metal composition of most samples was below that of the diesel with exception of Mn, Pb and Zn. The total acid numbers of all samples were below that of diesel and would not cause corrosion. It is recommended that processing of these samples should be done to conserve fossil fuel and as alternative diesel fuels in diesel engines.

KEY WORDS: Biodiesel fuel, Palm oil, Palm oil methylester, Ester-diesel blends

INTRODUCTION

The invention and widespread of internal combustion engines at the beginning of the 20th century caused a radical revolution in petroleum refining. Ever since then, immense progress has been made to make diesel fuel better known and produced throughout the world, particularly in the western world where the technology of petroleum refining has enjoyed immense improvement through the use of modern science research and engineering applications.

When the diesel engine was invented, vegetable oils were used as the first liquid fuel after coal dust [1]. However, their use was abandoned when comparatively inexpensive petroleum based fuel became available. The petroleum-based fuels, besides offering an economic advantage were free from many of the problems, which have been with the use of vegetable oils as fuels. The problems associated with the use of vegetable oils include: injector fouling, ring sticking and varnish build up on the cylinder wall. Most of the problem associated with the use of vegetable oil can be attributed to the high viscosity of vegetable oil and to the reactivity of the polyunsaturated fatty acid components of the triglycerides. Research has shown that the viscosity problems can be overcome by a chemical reaction to form alcohol esters. These fatty acid esters have shown promise as alternative diesel fuels [1].

Nowadays, there is an extensive bibliography on all subjects ranging from sources, raw materials for production, its improvement, quality and grades of refined diesel, different application and its adaptation as indeed one of the most important petroleum fraction for driving heavy trucks. More so, the specific production process data and information are important to

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researchers and industrialist who are continuously looking forward to improved process condition of the plant, product and the environmental safety [1].

Clearly, up to certain point, we are faced with two contracting tasks. Through its economic interest, there is no doubt that fossil diesel plays a vital role in the generation of energy to drive automobiles and mechanics but recent surveys has indicated that at the present rate of energy consumption, since the fossil oil is the major source of energy, there is continued decline in quantity of crude petroleum which serves as source for diesel oil production. Moreover, the rate of replacement is not proportional to the consumption. For example, in Nigeria at the end of 1986 there was sufficient oil remaining to last about 34 years, natural gas for 58 years and coal for 219 years. Long before these resources are finally exhausted, oil in particular will become scarce, inevitably more expensive [2].

Through its environmental relations, the immediate and post impact effect of oil spillage and pollution has done much to destroy the live of the communities, vegetation and aquatic lives.

The above mentioned problems and other facts, necessitated further search or rather awakened new interest for vegetable oil improvement as alternative source. This potential energy source is renewable, it could reduce the risk of unavailability of fossil diesel and could to a large extent reduce pollution effects resulting from their wastes. Furthermore, there is no doubt that this will boost agriculture as more seeds will be required.

Literature has shown that oil from peanut (*Arachis hypogea*), sugarcane bagasse, rapeseed and other seed oils taken in order has been investigated by Quedraego *et al* [3], Sood [4], Krepeka [5], Kalayasiri *et al*. [6], and Federal and Lander Government [7], for their physical and chemical properties enabling them to be used as alternative fuel oils in diesel engine.

Research has also shown that suitable blends of some vegetable oils in the form of their methylester with diesel oil (fossil) can also serve as substitute for diesel oil. These oils include rapeseed oil, tallow oil, soybean, cottonseed, and other seed oils [1, 5, 8, 9].

The use of diesel (a fraction of petroleum refining) as fuel in automobile and as an industrial raw material dated immemorial, but because of industrialization and wide spread of automotive engine and decline in diesel supply, there is need to produce vegetable oils (based diesel), to supplement the fossil based diesel whose supply is continually being depleted.

Vegetable oil which can be either edible or non edible as extracted, does not have the best quality as fuel hence the need for refining (treatment).

In recent years, there has been considerable amount of research worldwide on alternative diesel fuel qualities; the emphasis has been on finding the key fuel properties that influence emission so that fuels that assist improving air quality can be formulated. An understanding of physical and chemical fuel properties of alternative diesel oil can assist the user, the refiners and the formulators to develop alternative fuels for diesel engines. Hence, this research is being done to study the key fuel properties of palm oil, its methylester and the blends of methylester with diesel (AGO).

The oil palm (*Elaeis guinensis*, family – palmae) is the most important economic crop in the tropics. It is the most important source of oil and produces more oil per acre than many of the oil producing crops. It has two types of oils – palm oil and palm kernel oil. Palm oil is extracted from the stone part called kernel. The two oils have distinct properties and are used for different purposes. Palm oil is used for the manufacture of soap, production of margarine lubricating oils, candle and in tinplate and sheet industries. Palm kernel oil is used for soap, margarine manufacture and vegetable oil production while the cake left after production is used for livestock feed manufacture. The oil palm occurs between latitudes 15^o N and 12^o S and it requires an average temperature of 23 ^oC to 25 ^oC to survive. The rainfall requirement is 100 cm to 150 cm average and an optimum of 200 to 400 cm rainfall [10].

EXPERIMENTAL

Sample collection and preparation

Palm oil was bought from the local market. The diesel oil used as standard was purchased from a petrol station in Awka – Nigeria. The palm oil was purified by degumming, alkali refining and bleaching as outlined by Ajiwe, A.O.C.S., and Tandy and McPherson methods [11-13]. Palm oil was used to prepare soap. The soap was made by pouring in 150 mL of NaOH (made by dissolving 47.5 g NaOH in 150 mL distilled water) into 300 mL of palm oil with vigorous stirring. The soap was redissolved in boiling water, salted out with brine and then redissolved in water and was acidified with 1:1 HCl to produce the fatty acid mixture and was methylated with methanol in the ratio of 1 fatty acid mixture to 6 volumes of methanol in presence of 10 mL of 1:1 H_2SO_4. The methylester was formed after heating the mixture to boil for 20 minutes. Palm oil ester was separated using a separatory funnel. Similarly, palm oil ester was prepared from the precipitated fatty acid by reacting it with methanol in presence of sodium hydroxide solution as a catalyst [14]. The prepared methylester was to make nine dilutions of fossil diesel (AGO) in the ratios: 10:90 – 90:10. The purified palm oil, its methylester, methylester dilutions with diesel oil in the ratios: 10:90, 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 80:20, 90:10 and diesel (AGO) were comparatively analyzed for their primary fuel properties such as relative density, total acid value, viscosity, water content, calorific value, ash contents, flash point, carbon residue and trace elements. Also, the bond structure and stability of samples were monitored with a Fourier transform infrared spectrometer at 28, 50, 100, 150 and 200 ^{o}C (heating and cooling).

Calorific value, relative density, water content and ash content of all samples were determined by methods outlined by A.O.C.S. (American Oil Chemist Society) [12], Usoro *et al*. [15], Clark [2], and Williams [16], respectively. The acid value was determined by the method outlined by Mahatta [17], while the kinematic viscosity was determined by the Institute of Petroleum (IP) [18], and standard method [19]. The flash point and carbon residue were determined by the American Society for Testing and Materials (ASTM) method [20]. Each sample was tested for its diesel engine powering capability in comparison to diesel oil. The engine used was a small fabricated diesel engine for pumping tyre.

RESULTS AND DISCUSSION

Table 1 shows the comparative analyses of the palm oil, methylester blends with diesel and diesel. Table 2 depicts the trace metal composition of the samples while Table 3-7 are the infrared spectral data to compare the bond structure – stability at 28, 50, 100, 150 and 200 ^{o}C.

The physical and chemical analysis results of palm oil, its methylester and ester blends with diesel have shown that novel vegetable diesels could be obtained from palm oil. Most blends 30:70 to 70:30 fell within 2D grade diesel while the palm oil, methylester and 90:10 blend fell into 4D grade diesel. The 10:90 and 20:80 fell within 1D grade diesel. The bond structure/stability relationship deduced from Fourier transform infrared spectra (FTIR) confirmed the structure of palm oil, ester, ester/diesel blends as being similar to that of the standard diesel (AGO) (see Tables 3-4). The methylester was found to be a better diesel than the oil from bond structure/stability relationship and viscosity.

The ash contents of most samples were all within the ASTM limiting requirements of 0.01% for the first, second and 4D grade diesel fuels. This confirmed that the compounds contained burnable materials which made them less likely to contribute to injector, fueld pump, piston and ring wear. The relative density of most samples showed that 10:90 to 60:40 were very close to that of the diesel while those of the methylester, 70:30 to 90:10 blends were above – that of the diesel. But all the samples had calorific value close to that of diesel. Literature had confirmed that a low relative density indicated a predominantly paraffinic fuel with good ignition properties in diesel engines while high relative density indicated mainly aromatic or asphaltic fuel with poor combustion properties [2, 20].

Table 1. Comparative analysis results of palm oil, methylester, ester blends with diesel and diesel.

Sample	Flash point °C	Relative density	Carbon residue (% wt)	Water content (% wt)	Caloric value (kJ/kg)	Ash content (% wt)	Viscosity mm^2/s	Acid value (mg/g)
Diesel	120	0.8701	0.17	0.03	44938	0.002	2.0	0.23
Palm oil	90	0.9183	0.38	0.05	43938	0.004	5.8	6.78
Palm oil ester	60	0.9168	0.22	0.008	45520	0.002	4.6	2.72
10PO : 90D	65	0.8498	0.05	0.07	44752	0.003	1.4	1.35
20PO : 80D	64	0.8795	0.07	0.005	44752	0.002	1.96	1.45
30PO : 70D	71	0.8775	0.14	0.002	44543	0.002	2.45	1.52
40PO : 60D	75	0.8853	0.13	0.001	44543	0.002	3.20	1.64
50PO : 50D	80	0.0053	0.10	0.002	44543	0.002	3.5	1.40
60PO : 40D	83	0.8932	0.26	0.005	44543	0.002	3.65	1.50
70PO : 30D	87	0.8934	0.29	0.001	44543	0.002	3.85	1.60
80PO : 20D	75	0.8932	0.37	0.007	44543	0.003	4.2	1.7
90PO : 10D	83	0.8932	0.57	0.008	44543	0.003	4.53	1.8

Table 2. Trace metal composition of palm oil ester, diesel and ester/diesel blends in relation to corrosion (mg/g).

Trace metal	Palm oil	Palm ester	10PE : 90D	20PE : 80D	30PE : 70D	40PE : 60D	50PE : 50D	60PE : 40D	70PE : 30D	80PE : 20D	90PE : 10D	Diesel
Fe	0.7267	0.6767	2.935	2,915	2,820	3.073	2,814	3.254	3.102	2.712	2.126	6.300
Pb	0.227	0.110	0.051	0.065	0.044	0.092	0.041	0.048	0.071	0.074	0.076	0.079
Cu	0.022	0.0170	0.1056	0.0914	0.0878	0.0781	0.1188	0.1481	0.1171	0.0852	0.0931	1.165
Mg	0.1933	0.1433	0.2259	0.3349	0.2815	0.3082	0.5056	0.2596	0.3879	0.2913	0.3412	1.497
Mn	0.0291	0.0241	0.1574	0.1495	0.1280	0.1537	0.1469	0.1438	0.1574	0.1165	0.1269	0.1365
Cr	0.1532	0.0103	0.2359	0.2262	0.2409	0.2852	0.1769	0.2802	0.1810	0.2802	0.1967	0.5154
Zn	0.2762	0.2262	0.9589	0.6893	0.9928	1.079	0.9236	1.324	1.571	0.9149	1.109	1.926
Ni	0.5982	0.2670	1.122	1.201	1.135	1.285	1.083	1.248	1.117	1.120	1.177	1.716

PE = Palm oil ester. D = Diesel.

The viscosities of most blends 30:90 to 80:20 all fell within the grade 2 diesel fuels with 2-4.3 mm^2/s. The viscosities of 10:90 and 20:80 were within 1D grade diesel (1.4 to 1.9 mm^2/s as standard) [20]. The oil, methylester and 90:10 ester – diesel blend had viscosities that placed them in the heavy diesel fuel class (4.4 – 24.0 mm^2/s) [20]. Note that these viscosities are further confirmed by closeness in bond structure of the diesel with methyl ester and the blends. The oil had higher water content than that of the diesel (AGO) while the methylester and blends had lower water content, but all samples had water content within the ASTM standard of 0.25% [20]. The flash point of all samples were below that of the standard diesel but none was lower than 60 °C. This confirmed that the storage of these samples would not constitute a fire risk since their flash point placed them in the number 2 and 4 grade diesel fuels.

The acid value of the oil, ester and blends were higher than that of diesel but are relatively low in terms of mg/g. Note worthy was the fact that acidity comes from fatty acid composition of the oil and ester unlike that of fossil diesel fuel which comes from sulfur content. The fatty acid composition of all palm oil was greatly reduced during purification, saponification and esterification and would not cause corrosion in diesel engine [12, 13]. It had been estimated that reduction of sulfur content of fossil fuels from 0.3% national average to 0.05% would increase the life of engines by 30 percent. It had been also estimated that reducing sulfur and aromatic to the recommended levels would cost about 1.5% per gallon of fuel. This thinking would come from these alternative fuel blends [16, 20, 21]. It was obvious that blending would dilute both sulfur and aromatic in the fossil diesel fuels. The acid value, sulfur, and aromatic reduction were very much evident in the reduction of carbon residues of blends 10:90 to 50:50. These confirmed that engine performance of most fossil diesel could be improved by mere dilution with a vegetable oil ester.

Table 3. IR spectral data (cm^{-1}) showing bond structure/stability comparison for palm oil, palm oil methylester, ester-diesel blends and diesel at 28 °C.

Palm oil	Palm oil methyl ester	Diesel	10:90 Ester: diesel	20:80 Ester: diesel	30:70 Ester: diesel	40:60 Ester: diesel	50:50 Ester: diesel	60:40 Ester: diesel	70:30 Ester: diesel	80:20 Ester: diesel	90:10 Ester: diesel	Description
3329	-	3426	3449	3441	3454	3454	3453	-	-	-	-	Free O-H stretch
3005		3166									3005	O-H stretch
2924	2921	2926	2924	2925	2923	2924	2924	2923	2922	2927	2921	C-H stretch for alkenes and aromatics
2854	2851	2855	2855	2855	2853	2854	2854	2854	2853	2854	2851	C-H stretch for alkanes
1745	1742	1746	1745	1712	1711	1743	1744	1743	1743	1709	1743	C=O stretch for esters
	1709	1604	1711	1603	1621	1711	1711	1711	1711		1710	
1464	1463	1461	1462	1462	1444	1462	1462	1463	1463	1462	1436	C=C stretch for alkenes and
1378	1411	1306	1378	1378	1379	1378	1377	1377	1377	1377	1377	aromatics
1238	1294	-	-	-	1284	1284	1284	1286	1294	1287	1295	C-O stretch for esters and
	1205	-	-	-	-	-	-	1216			1226	ethers
1162	1098	1167	-	-	-	-	-	-	-	1112	1118	C-O deformation bonds
1116	1036	1033	1033	1039	1033	937	936	938	937	935	1034	C-H deformation for alkyl
	936	870			937						939	and aryl groups
721	721	745	722	746	722	722	722	722	722	721	721	C-H deformation for methyl groups

Table 4. IR spectral data (cm^{-1}) showing bond structure/stability comparison for palm oil, palm oil methylester, ester-diesel blends and diesel at 50 °C.

Palm oil	Palm oil methyl ester	Diesel	10:90 Ester: diesel	20:80 Ester: diesel	30:70 Ester: diesel	40:60 Ester: diesel	50:50 Ester: diesel	60:40 Ester: diesel	70:30 Ester: diesel	80:20 Ester: diesel	90:10 Ester: diesel	Description
3472	3389	3426	3416	3382	-	3388	-	-	-	-	-	Free O-H stretch
3250												
3005	3005							3005	3005	3005	3005	O-H stretch
2923	2922	2923	2923	2924	2924	2924	2924	2923	2923	2923	2923	C-H stretch for alkene and aromatics
2853	2851	2854	2853	2854	2853	2853	2852	2852	2852	2853	2854	C-H stretch for alkanes
1746	1742	1746	1712	1744	1754	1744	1744	1743	1743	1743	1744	C=O stretch for esters
1711	1710	1666		1712	1712	1712	1712	1711	1711	1711	1711	
1464	1463	1457	1454	1462	1457	1463	1457	1463	1463	1463	1461	C=C stretch for alkenes and aromatics
1378		1377	1379	1377	1377	1378	1376	1377	1377	1377	1377	C-O stretch for esters and ethers
1239	1295				1285		1285	1296	1295	1295	1284	C-O deforma-tion bonds.
1164	1170	1164		1168								
1098	939	1032	1098		1033	1096		1033				C-H deformation for
		851	1034		936	938	938	940	940	940	937	alkyl and aryl groups
722	721	722	722	722	722	722	722	722	722	721	721	C-H deformation for methyl groups

Table 5. IR spectral data (cm^{-1}) showing bond structure/stability comparison for palm oil, palm oil methylester, ester-diesel blends and diesel at 100 °C.

Palm oil	Palm oil methyl ester	Diesel	10:90 Ester: diesel	20:80 Ester: diesel	30:70 Ester: diesel	40:60 Ester: diesel	50:50 Ester: diesel	60:40 Ester: diesel	70:30 Ester: diesel	80:20 Ester: diesel	90:10 Ester: diesel	Description
3424	3424	3426	3425	3476	3416	3443	3440	-	3441	3423	3445	Free O-H stretch
3006	3006								3006	3006	3006	O-H stretch
2924	2923	2925	2923	2924	2925	2924	2924	2924	2924	2924	2924	C-H stretch for alkene and aromatics
2853	2852	2853	2854	2854	2854	2854	2853	2853	2852	2851	2853	C-H stretch for alkanes
1746	1743	1746	1745	1744	1744	1744	1744	1744	1743	1743	1743	C=O stretch for esters
1711	1711	1711	1712	1712	1712	1711	1711	1711	1710	1709	1710	
			1606	1605								
1464	1463	1464	1458	1460	1460	1463	1463	1463	1463	1464	1464	C=C stretch for alkenes and aromatics
1378	1377	1378	1377	1377	1377	1377	1378	1377	1377	1377	1377	C-O stretch for esters and
											1377	ethers
1240	1225	1240	1301	NP	1245	1288	1296	1296	1296	1296	1296	C-O deformation bonds
									1225		1205	
1166		1166	1164	NP	NP	1205	1170	1171	1119	1188	1032	C-H deformation for alkyl
1098	1097	1098	1034	NP	1033	1096	1032		1032	1097		and aryl groups
961	940	961				939	940	937	940	940		
722	722	722	722	722	722	722	722	722	722	722	722	C-H deformation for methyl groups
								690		547	548	C-H deformation for alkyl groups

Table 6. IR spectral data (cm^{-1}) showing bond structure/stability comparison for palm oil, palm oil methylester, ester-diesel blends and diesel at 150 °C.

Palm oil	Palm oil methyl ester	Diesel	10:90 Ester: diesel	20:80 Ester: diesel	30:70 Ester: diesel	40:60 Ester: diesel	50:50 Ester: diesel	60:40 Ester: diesel	70:30 Ester: diesel	80:20 Ester: diesel	90:10 Ester: diesel	Description
3444	3443	3418	3443	3443	3442	3421	3444	3418	3444	3441	3441	Free O-H stretch
3005	3005	-	2953	-	-	-	3004	3005	3005	3005	3006	O-H stretch
2925	2925	2925	2924	2924	2924	2924	2924	2924	2923	2924	2924	C-H stretch for alkene and aromatics
2855	2852	2854	2854	2855	2853	2853	2853	2853	2853	2850	2851	C-H stretch for alkanes
1742	1742	1747	1746	1744	1744	1744	1744	1744	1744	1743	1743	C=O stretch for esters
1710	1710	1714	1712	1712	1712	1709	1712	1711	1711	1707	1710	
			1606	1605								
1469	1463	1458	1458	1458	1463	1463	1463	1463	1463	1463	1463	C=C stretch for alkenes
1414					-	1411	-	1412		1411	1436	and aromatics
1350	1376	1377	1377	1377	1377	1379	1377	1377	1377	1376	1376	C-O stretch for esters and ethers
1266	1296	1307		1287	1297	1297	1288	1297	1295	1297	1297	C-O deformation bonds
	1203	1162				1226	1205	1205	1204	1204	1205	
1177	1098	1099	1162	1167	1167	1098	1097	1098	1098	1098	1118	
1099	1033	1033	1033	1033	1033	1031	1033	1032	1033	1032	1032	
942	940	874	877	940	940	941	939	940	939	940	940	C-H deformation for alkyl
		782				812				782		and aryl groups
720	721	722	722	722	722	721	721	722	721	721	722	C-H deformation for
									-			methyl groups
			537	669	669	669		547		688	688	C-H deformation for
				537	537	547	-			547	547	alkyl groups

Table 7. IR spectral data (cm^{-1}) showing bond structure/stability comparison for palm oil, palm oil methylester, ester-diesel blends and diesel at 200 °C.

Palm oil	Palm oil methyl ester	Diesel	10:90 Ester: diesel	20:80 Ester: diesel	30:70 Ester: diesel	40:60 Ester: diesel	50:50 Ester: diesel	60:40 Ester: diesel	70:30 Ester: diesel	80:20 Ester: diesel	90:10 Ester: diesel	Description
3472	3454	3474	3454	3454	3442	3442	3424	3442				Free O-H stretch
3005	3006	3008			2953	3005	3005	2953	3005	3005	3006	O-H stretch
2925	2925	2923	2924	2924	2924	2924	2923	2922	2922	2922	2922	C-H stretch for alkene and aromatics
2855	2853	2854	2854	2854	2853	2852	2853	2853	2853	2853	2853	C-H stretch for alkanes
1744	1743	1246	1745	1744	1744	1743	1743	1743	1743	1743	1742	C=O stretch for esters
1711	1711			1711	1711	1710	1711		1710	1710	1709	
1467	1437	1463	1462	1463	1463	1463	1463	1463	1463	1463	1463	C=C stretch for alkenes
1415						1411			1411	1411	1436	and aromatics
1377	1351	1378	1377	1377	1377	1347	1377	1377	1377	1376	1376	C-O stretch for esters and ethers
1265	1296	1238		1287	1287	1297	1296	1296	1296	1296	1296	C-O deformation bonds
	1204					1205			1205	1247	1205	
1176	1118	1164		1033		1119	1097	1117		1188		
1099	1030									1097	1098	
943	940	1110								1010		
	782			939	940	940 812	940	940	940	940 782	940	C-H deformation for alkyl and aryl groups
722	722	722	722	744	722	722	722	722	722 -	722 688	721	C-H deformation for methyl groups
							-		547	547		C-H deformation for alkyl groups

Cetane number depends primarily on the hydrocarbon composition of a fuel, therefore bond structure/stability relationship could be used to relate cetane number of fuels. The diesel spectra and those of the samples were very close and must have a similar cetane number (see Table 3). The stability of the samples when compared to the diesel showed that the samples were stable at room temperature (28 °C), 50 °C and 100 °C. At 150 °C more alkyl groups were deformed but the bonds were still stable for most sample while at 200 °C there was complete deformation of C-H groups of alkyl and aryl groups of all samples with the exception of the oil and the diesel (AGO). This bond structure relationship confirmed that methylester and the blends were equivalent diesel fuels and that palm oil if heated to 200 °C and cooled would act as an equivalent diesel fuel in diesel engines [18].

The trace metal composition of all the samples (Table 2) were below that of the standard diesel with the exception of Mn, Pb and Zn. These values confirmed that all samples would not constitute a corrosion problem in the injector and piston chambers of diesel engines. Performance test carried out with a diesel machine for pumping tyre tubes on the oil, methylester, and ester/diesel blends of all samples confirmed that methylester and blends would serve as alternatives to fossil diesel [18, 22].

CONCLUSION

The results of this study have confirmed that methylester and ester-diesel blends of palm oil could be utilized in place of diesel in diesel engines. Palm oil is recommended as a heavy diesel fuel when heated up to 200 °C and cooled. Blending of fossil fuel with vegetable fuel has been recommended so as to reduce the carbon residue and acidity of fossil fuels. The use of methylesters, and blends would certainly reduce pollution of the environment by ordinary fossil diesel, would help boost agriculture and would help conserve the fossil fuel.

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