INVESTIGATION OF LOCUST BEAN AND NEEM OILS AS ALTERNATIVE FUELS FOR DIESEL ENGINES

By

Yawas, D. S., Anafi F. O., Suleiman R. B. O., Kulla D. M., Jumare, A. M. and G. D. Ali

Department of Mechanical Engineering
Ahmadu Bello University, Zaria.

ABSTRACT

In this study, the possibility of using locust bean and neem oils as fuel oil alternatives has been investigated. Based on this, locust bean oil and neem oil were extracted, their methylesters were prepared and the fuel properties such as flash point, acid value, relative density, viscosity, carbon residue, ash moisture and calorific value for each were determined. The atomic absorption spectroscopy results of the microelement compositions of the samples showed that the metallic contents would not cause corrosion.

A performance test was carried out on each of the oils using a leyland compression ignition engine and the results confirmed that locust bean methylester and neem methylester and their blends could be used as substitute for diesel oil in diesel engines.

INTRODUCTION

The over dependence on petroleum and its processed products to the exclusion of other resources for fuelling of engines and economic development in our country, Nigeria is a very dangerous position. Recent research findings have indicated that the present rate of energy consumption is geometrical. (Ali,2005, Bello, et al, 2003, Ajiwe et al, 2003, Canakei, et al, 2001). However, the rate of replacement is not proportional to the rate of consumption. For example, in Nigeria at the end of 1986 there was sufficient oil remaining to last 34 years, natural gas for 58 years and coal for 219 years, but long before these resources are finally exhausted, oil in particular will become scarce and inevitably more expensive (Yusuf, 2001, Omotola, 2001, Ajiwe, 2003, Canakei and Van Gerpen 2001). For the past few years there has been high increase in diesel fuel demand, which has caused serious scarcity in Nigeria. This increase in price and the scarcity of fuel supplies in the last and present decades have promoted interest in development of alternative sources of liquid fuels in Nigeria. The main interest lies in developing a renewable biomass source of fuel supply (Ali, 2005; Bello et al, 2003).

Fats and oils were used as the fuel for diesel engine but were dropped for the cheap fossil diesel due to discovery and use of petroleum-based fuels in the 20th century (Schumacher, et al., 2001). Though fossil fuel has an economic advantage, its immediate and past impact on the environment through spillage and other ecological degradation has done much to destroy the aquatic life of the riverine communities and surrounding vegetation.

Therefore, there is need to shift to biodisel fuel, since the raw materials are abundant and regenerative through improved agricultural activities. Bio diesel oils are biodegradable and their use avoids upstream pollution. They are low in toxicity and do not damage aquatic organism (Oseni et al, 2006, Bello et al, 2003, Ajiwe et al, 2005).

PURPOSE AND OBJECTIVE

The purpose of this study was to compare bio diesel (transesterified locust bean and neem oils) and bio diesel/heavy alkylate blends with conventional petroleum diesel fuel when fuelling a leyland engine to measure and compare properties and engine performance.

One of the numerous raw materials Nigeria is endowed with is the West African locust bean tree, parkia clappertoniana, keay (Shok, 1992) which bears fruits consisting of pods. It belongs to one of the leguminous families called minnosceae. It consists of powdery matter, seeds and the husk. 30% of the seed is seed oil (Shok, 1992).

Similarly, neem oil is obtained from fully matured seed of *azadirachta indica* juss of the family of meliaceae. The plant is found throughout Africa, India and other Asian Countries. It is a yellow coloured oil and is soluble in alcohol. The oil contains 2% of bitters, used for the anti-viral activity and soap making (Opeke, 1992).

This study seeks to renew interest in the use of vegetable based oils as fuel alternatives for diesel engines. Apart from the work done on the use of locust bean husk and neem oil as corrosion inhibitors (Yawas, 2005), no work has been done on the fuel properties of the oils.

MATERIALS AND METHODS

Materials

The oil, locust bean and neem were extracted using a Gyl-78A Serew Oil press, made in China and available at AMIL Industrial Limited, Kawo Kaduna.

The diesel oil was bought from Conoil Petrol Station in Samaru, Zaria.

Methylester Sample Preparation

The methyl ester samples were prepared by saponification of the oil sample, acidification of the soap followed by methylation (esterification) of the fatty acid so formed using the method outlined by Ajiwe, et al, (2001). The methylester was blended with a standard diesel oil in the ratios 30:70, 40:60, 50:50 of locust beans and neem methylesters to diesel oil (Ali, 2005).

Analysis of the Samples

The extracted oils of neem and locust beans, the methyl ester, the methylester blends with diesel and the diesel oil were comparatively analyzed for their primary fuel properties such as relative density, carbon residue, viscosity, flash point, calorific value, total acid value, ash and moisture contents. These properties were determined by the methods prescribed by the American Standard for testing and materials (ASTM), 1985 and that of the Institute of Petroleum Standard (IPS), 1983. The microelements were determined by Atomic Absorption Spectroscopic (AAS) method.

Engine Experimentation

The engine used was a four stroke, four cylinder engine of the Leyland compression ignition type (compression ratio 21:5.1), available in the department mechanical engineering, A.B.U Zaria. It was run using diesel, oil ester, and blend with the biodisel.

Procedure

Before starting the test, the dynamometer was checked to make sure the static balance was correct. In starting up, the inlet valve was opened fully and outlet valve very slightly opened. It is advisable in most cases to start up with a light load, and this may be accompanied by screwing the sluice gates as far as they would go into the machine. The engine was started with all valves in the piping between the source of water supply and dynamometer inlet fully open. The hand wheel provided on top of the balance frame was to adjust the height of the balance arm. This should always be set to the horizontal when taking the brake horsepower (Bhp). The fuel consumption was obtained by noting the fit for the consumption of known quantity of fuel using a stopwatch. A constant load was used to start each experiment. The cooling inlet and outlet temperatures were obtained by thermometers. Observations were made on the fuel consumption, load, speed, cooling water, exhaust temperature, oil pressure and manometer reading each time the engine consumes 50ml of fuel.

The trial was commenced using 100% diesel, later with the blends and oil esters. The result obtained and tabulated in Tables 1 – 9.

Experimental Calculation

i. Torque, $T = \frac{FL}{100}(Nm)$

where, F = balance readings, (15N)

L = torgue arm length, (15cm)

$$\therefore\ T = \frac{15 \times 15}{100} = 2.25Nm$$

ii. Brake horsepower, Bhp $= \frac{F \times N}{K}$

where, F. = 15N

N = speed = 1000

K = Engine constant = 4500

$$\therefore \text{Bhp} = \frac{15 \times 1000}{4500} = 3.33kW$$

iii. Fuel consumption

$$V = \frac{3600 \times V_G}{t}$$

where, VG = calibrated volume of fuel gauge (liters) = 50ml

t = time to fuel calibrated volume, second (s) = 79.8s

V = fuel consumption (liters/hour)

$$\therefore \frac{3600\times 50\times 10}{79.8} = 2.25611hr$$

iv. Specific fuel consumption

$$V = \frac{V}{Bhp}$$

where, V = fuel consumption = 2.2561/hr

Bhp = brake horsepower = 3.33kw

V = specific fuel consumption (1/kWh)

$$\therefore v\frac{2.256}{3.33} = 0.6781/kWh$$

v. Swept volume

$$V_s = \frac{\pi d^2 Sn}{4\times 10^6}$$

where,

d = cylinder diameter = 84.14mm

S = piston stroke = 101.6mm

n = number of cylinders = 4

$$\therefore \text{Vs} = \frac{\pi\times 84.14^2\times 101.6\times 4}{4\times 10^6} = 2.261^3$$

vi. Brake Mean effective pressure

$$\overline{P} = \frac{6\times 10^4\times P\times K_2}{N\times Vs}$$

where, $\overline{P}$ = b.m.e.p)kN/m^2)

Vs = Swept volume of engine = 2.261^3

K_2 = constant = 2 for 4 – stroke engine

$$\therefore \overline{P} = \frac{6\times 10^4\times 3.33\times 2}{1000\times 2.26}$$

vii. Mechanical Losses, M (kW)

$$\text{M} = \frac{TN}{K`} = \frac{2.25\times 1000}{4500}$$

$$= 0.5\text{kW}$$

viii. Indicted Power, I. (KW)

$$\text{I} = \text{P} + \text{M}$$

$$= 3.33 + 0.5 = 3.83\text{kW}$$

ix. Mechanical Efficiency, η_{mech}

$$\eta_{mech} = \frac{P}{P+M} = \frac{P}{I}$$

$$= \frac{3.33}{3.83}$$

$$= 0.8695$$

$$= 86.95\%$$

Similarly other values were calculated and are shown in tables 5 - 8

Table 1: Physiochemical Properties of the Reference Diesel fuel from Kaduna Refinery and Physiochemical Company Kaduna

Parameter	Value
Specific gravity (15^0)	0.85
Diesel Index	47 max
Distillation temperature (^{0}C)	128
Recovering (357^0C % vol)	90 min
End boiling point (^{0}C)	385 max
Flash point (^{0}C)	65.6
Total sulphur content (%wt)	0.5 max
Kinematic Viscosity (m3/s)	1.6 – 5.5
Cloud content (%wt)	4.4 max
Ash content (%wt)	0.01 max
Water (%wt)	0.05 max
Sediment (%vol)	0/01
Calorific value (MJ/kg)	65 max

Table 2: Physiochemical Properties of Neem and Locust Bean Oils

Oil samples / Properties	Diesel	Neem	Locust bean
Relative density (15^0C)	0.85	0.9220	0.9183
Flash Point (^{0}C)	65/6	85	86
Viscosity (centistokes, 37.8^0C)	50	65.1	43.79
Calorific value (MJ/Kg)	65	35.9204	35.6473
Carbon content (%wt)	-	13.9	13.3
Ahs content (%wt)	0.01	3.6	0.3
Saponification value (mg)	-	247.5	277.7
Acid value (mg/g)	-	17.37	14.96
Oleic acid C17H33COOH (%)	-	8.73	7.52

Table 3: Viscosity at various temperatures for sesame

Viscosity (x 10^{-6}) cst	Sesame
37.8	35.58
40	34.51
60	32.04

Table 4: Viscosity at various temperaut4res for Neem and Locust bean Seeds' Oil

Viscosity (x10-6)cst	Neem	Locust Bean
Temperature (0C)		
37.8	65.1	43.79
40	59.54	40.21
60	43.79	24.08

Table 5: experimental Results of Based Diesel Fuel

Diesel	Speed (rpm)	Load (N)	Coolant inlet	Coolant outlet	Exhaust (Temp (^{0}C)	Vol of Fuel Consume	Heat loss to coolant	Manometer reading	Oil pressure
100%	1000	15	23	53	80	50/1.33	30	5.5	47
	1250	21	24	56	100	50/1.17	32	7.8	57
	1500	25	24	62	115	50/1.53	38	13.6	53
	2000	33	24	65	118	50/2.25	41	15.3	57

Table 6: Performance Results of Blends of sesame oil and diesel fuel

PARAMETER	LB:D (30:70)			LB:D (40:60)					LB:D(50:50)			
Speed (rpm)	1000	1250	1500	1000	2000	1250	1500	2000	1000	1250	1500	2000
Load (N)	15	22.5	26	33	15	21.5	25	32	15	23	27	35
Torque (Nm)	2.25	3.38	3.9	4.95	2.25	3.23	3.75	4.8	2.25	3.3	4.05	5.25
Bhp (kW)	3.33	6.25	8.67	14.67	3.33	5.97	8.33	14.22	3.33	6.11	9.0	15.56
Fuel consumption (1/hr	2.13	1.81	2.52	3.6	2.14	1.82	2.59	5.00	2.06	1.79	2.46	3
Specific Consumption (1kWhr)	0.64	0.29	0.29	0.245	0.64	0.31	0.31	0.351	0.62	0.29	0.27	0.193
Swept Volume (l3)	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26
Brake Mean effective pressure (kN/m2)	176.8	265.5	306.9	389.5	176.8	253.6	294.9	377.5	176.8	259.5	318.6	413.1
Mechanical Loss (kW)	0.5	0.94	1.3	2.2	0.5	0.9	1.25	2.13	0.5	0.92	1.35	2.33
Indicted Power (kW)	3.83	7.19	9.97	16.87	3.83	6.87	9.58	16.35	3.83	7.03	10.35	17.89
Mechanical efficiency (%)	86.95	86.93	86.96	86.96	86.95	86.90	86.95	86.95	86.95	86.91	86.96	86.96

Table 7: Performance Results of Blend of Neem and Locust Bean oil esters and diesel fuel

PARAMETER	NM:D (50:50)			LBE:D (50:50)				
Speed (rpm)	1000	1250	1500	2000	1000	1250	1500	2000
Load (N)	15	18	21.5	1.39	15	19.5	23	0.5
Torque (Nm)	2.25	2.7	3.23	4.28	2.25	2.93	3.95	4.5
Bhp (kW)	3.33	5.00	7.17	12.67	3.33	6.5	7.67	13.33
Fuel consumption (1/hr	1.94	1.26	1.46	2.16	2.06	1.45	2.21	6.00
Specific Consumption (1kWhr)	0.58	0.25	0.20	0.17	0.62	0.22	0.29	0.45
Swept Volume (l3)	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26
Brake Mean effective pressure (kN/m2)	176.8	212.4	253.8	336.37	176.8	276.1	271.5	353.89
Mechanical Loss (kW)	0.5	0.75	1.08	1.9	0.5	0.98	1.15	2.00
Indicted Power (kW)	3.83	5.75	8.25	14.57	3.83	7.48	8,82	16.35
Mechanical efficiency (%)	86.95	86.96	86.91	86.95	86.95	86.90	86.96	86.96

Table 8: Performance Results of Blends of Neem Oil and Diesel fuel

PARAMETER	NM:D (30:70)			NM:D (40:60)					NM:D(50:50)			
Speed (rpm)	1000	1250	1500	2000	1000	1250	1500	2000	1000	1250	1500	2000
Load (N)	15	20	24	34	15	23	31	47	15	22	29	43
Torque (Nm)	2.25	3.00	3.6	5.1	2.25	3.45	4.65	7.05	2.25	3.3	4.35	6.45
Bhp (Kw)	3.33	5.56	8.00	15.11	3.33	6.39	10.3	20.89	3.33	6.11	9.67	19.11
Fuel consumption (1/hr	2.00	1.77	2.46	3.46	2.14	1.82	2.56	4.29	1.37	1.55	2.10	2.09
Specific Consumption (1kWhr)	0.6	0.32	0.228	0.228	0.64	0.29	0.25	0.21	0.41	0.25	0.22	0.11
Swept Volume (l3)	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26
Brake Mean effective pressure (kN/m2)	176.8	236.2	401.2	401.2	176.8	271.4	365.7	365.7	176.8	259.5	342.3	507.4
Mechanical Loss (kW)	0.5	0.83	2.27	2.27	0.5	0.96	1.55	1.55	0.5	0.92	1.43	2.87
Indicted Power (kW)	3.83	6.39	17.38	17.38	3.83	7.35	11.9	11.9	3.83	7.03	11.1	21.18
Mechanical efficiency (%)	86.95	87.00	86.96	86.96	86.95	86.94	86.95	86.95	86.95	86.91	86.96	86.96

Table 9: Metal Composition of the oils (mg/g)

Trace metal	Neem oil	Locust bean oil
Fe	0.540	0.47
Pb	0.056	0.06
Cu	0.038	0.040
Mg	0.294	0.320
Mn	0.0196	0.0180
Cr	0.251	0.240
Zn	0.692	0.580
Ni	0.417	0.400

RESULTS AND DISCUSSIONS

The results of the comparative analysis of the locust bean and neem oils samples and the reference diesel oil are given in table 1 – 3. Table 2 shows the physico-chemical properties of locust bean and neem oils methyesters and esters blends

with the standard diesel oil. The resulting densities are in conformity with the ASTM requirement (ASTM, 1985). The low values of the relative densities of locust bean and neem methylests indicated good ignition property since literature reveals that high density indicates mainly aromatics or asphalted fuels with the attendant poor combustion tendency (Canakei, et al, 2001).

The trace metal compositions of all samples as shown (table 9) was below that of the standard diesel, hence these values confirmed that neem and locust bean vegetable fuels would not constitute a corrosion problem in the injection and piston chambers of the diesel engines.

The calorific values of the samples and the base diesel oil are very closely relate and high enough for good engine performance which is in agreement with IP standards of 1983.

The flash point of the point ranged from 65 – 86^{0}C, confirming that the fuels would not constitute a fire risk (Ajiwe et al 2000).

The viscosity of the oils, methylesters and blends are quite close to that of diesel and showed that they are sufficiently viscous (especially at high temperatures) and that real spray would be generated across the combustion chamber hence proper mixing with air.

Methylesters of vegetable oil (biodisel) have been found to have cleaner combustion tendencies and are environmentally friendly. It has been discovered that the long time effect of these substitutes on wear of valves, rings, pistons, sleeves, etc are within satisfactory range (Callahan, 1993).

From the values of torque and Brake horse power (Tables 5 – 8) there is clear indication that both of them increase with increase in speed for each of the oil esters and diesel blend chosen. This is in agreement with available literature (Clark et al 1988, Wu et al, 2001). Conversely, fuel consumption and specific fuel consumption decrease with increase in speed to a certain level which is in line with the institute of petroleum standards (IP), 1985, and Bagby, et al, 1987 findings.

CONCLUSION

The physico-chemical analysis and engine test results have demonstrated the possibility of using the locus beans and neem methylester blended with diesel fuel to run diesel engines.

Of the various blend proportion tested the 40:60 blend of neem and locus beans esters and diesel fuel gave higher maximum torque and power than 100% diesel fuel.

The most economical blend proportion in terms of fuel consumption and specific fuel consumption was 50:50, NM:D (2 litre/hr and 0.11 litre/kwhr).

The results of the flash point analysis suggest the samples oils would not constitute a fire risk.

The engine test analysis shows that neem oil has a better performance than locust bean oil but the overall performance of the two oil samples fall within the acceptable range of 4 – D grade diesel fuel. The disadvantage of high viscosity of the vegetable oils could be eliminated by conversion to form esters.

REFERENCES

1. V. I. E Ajiwe and E. A. Obika (2000). African pear seed oil, potential alternative source to diesel oil. Energy and fuels. American chemical society (Series 8), 14 (1) 1-5.

2. Ajiwe V. I. E., and V. O. Ajibola and C. M. O. A. Martins, (2001) possible vegetable diesel fuel from rubber seed oil (Hevea brasilensis), methylester and ester-diesel blends. African journal of sciences, 2, 277-289.

3. Ajiwe, V. I. E., V. O. Ajibola, and C. M. A. O. Martins,. (2003): Biodisel fuel from palm oil, Palm oil methylester and ester diesel blends

4. Ali G. D., , (2005): Studies on Alternative Fuels for Diesel engines. Unpublished B. Eng. Project. Department of Mechanical Engineering, Ahmadu Bello University, Zaria.

5. American Society for Testing and Materials (ASTM) (1985) ASTM pub. Pp. 31-36, 40-48, 103, 332-341,497-500.

6. Bello, E. I. and M. Okokoh,. (2003): Investigation of Soya bean and coconut oils as fuels for diesel engines. FUTAJET 2003, volume 3. pp. 1 – 4.

7. Callaham, T. J. (1993). Evaluation of Methyl Soyate/Diesel Fuel Blends as a Fuel for Diesel Engines. Final Report prepared for the American BioFuel Association by Southwest Research Institute Jefferson City, Mo.: National Biodiesel Board.

8. Canakei, M J. Van Gerpen (2001): Biodiesel production from oils and fats with high free fatty acids: Transaction of the ASAE 2001 pp. 22 – 25

9. Clark, G. H. (1988). Laboratory test on fuels and their significance in industrial and marine fuels. Reference book. Butter worth, Singapore. London pp. 4:3-21.

10. Institute of petroleum (IP)Standards (1983). IP Standards for petroleum and its products part 1. 42nd ed. IP pub. London.

11. Omotola, O. O. (2001) "Studies on alternative fuels for diesel engines unpublished final years projects 2001.

12. Opeke L., (1992): Economic Trees in the Tropics. Published by Longman Publishers, Ibadan.

13 Oseni, M. I., E. E Nnuka, and A. O. Ette, (2006) Evaluation of chemo-physical properties of selected Natural oils relevant to lubrication. Nigerian Journal of engineering research and development. Vol. 5 No. 2.

14. Plint, M. A. B. Sc. (Eng.), Ph.D., C.Eng., F. I. Mech. E; Instructional tests and experiments on internal combustion engines.

15. Schumacher, L. G. Clark, N, D. W. Lyons, W. Marshall (2001): Diesel engine exhaust emissions evaluation of Bodiesel blends using a Cummins L10E Engine: transaction of the American society of Agricultural engineers (ASAE) 2001. pp. 33-36.

16. Schumacher, L. G., W. Marshall, J. Krahl, W. B. Wetherell, M. S. Grabwski (2001): Biodiesel Emission data from series 60 DDC Engines: Transactions of the ASAE 2001 pp. 37 – 40. Shok, M. (1992): Locust Bean fruit as a potential source of chemical raw materials.

National Workshop on Industrial and Social aspects of Chemistry (INSAC), College of Arts and Science, Kano.

18. Wu, C.H., Lue, Y. F., Y. C. Chen (2001): Numerical stimulation of injection spray in a small D. I. Diesel Engine: A comparison of Dimethyl ether and diesel fuel: Transaction of the ASAE 2001.

19 Yawas, D. S. (2005): Suitability basement of some plant extracts and vegetable oils as corrosion inhibitors. Unpublished Ph.D Thesis. Dept of Mechanical Engineering, Ahmadu Bello University, Zaria.

20. Yusuf, D. E. et al (2001) comparison of the physical properties of groundnut oil blends with diesel oil" Nigerian Journal of Engineering, Ahmadu Bello University, (ABU) Zaria.