A STUDY OF SOME FUEL PROPERTIES OF LOCAL ETHANOL BLENDED WITH DIESEL FUEL

BY

Engr. Dr. E. A. Ajav and Mr. O. A. Akingbehin
e-mail:eaajav@skannet.com
Department of Agricultural Engineering, Faculty of Technology,
University of Ibadan, Ibadan, Nigeria.

ABSTRACT

Some fuel properties of local ethanol blended with diesel were experimentally determined to establish their suitability for use in compression ignition engines. Six blends (5, 10, 15, 20, 25, and 30%) of ethanol by volume with diesel were used. The properties determined were; relative density, viscosity, cloud and pour point, flash point and calorific value.

The results show that both the relative density and viscosity of the blends decreased as the ethanol content in the blends were increased. The cloud point was found to be 5^0C for all the blends and diesel while the pour point of –5,-7,-10,-13 and-36^{o}C were obtained for diesel and blends with 5, 10, 15 and 20% ethanol content respectively.

The pour point for two blends (25 and 30%) were not reached. Flash point of 74^{o}C was obtained for diesel while 24, 25, 27, 25, 25 and 26^{o}C were obtained for blends with 5, 10, 15, 20 25 and 30% ethanol respectively.

Calorific values of 44515, 43632, 43632, 43192, 42745, 41874, 41004, and 40577 kJ/kg were obtained for diesel and the ethanol-diesel blends respectively. Based on the findings of this study, blends with 5,10, 15 and 20 percent ethanol content were found to have acceptable fuel properties for use as supplementary fuel in farm engines.
Key words: Alternative fuels, Alcohol, Properties, Blends.

INTRODUCTION

Rising petroleum prices, increasing threat to the environment from exhaust emissions and global warming have generated an intense international interest in developing alternative non-petroleum fuels for engines. Ethanol has been identified as one of the possible alternative fuels (Yahya and Goering 1977). Ethanol can be produced from crops with high sugar or starch contents. Some of these crops include; sugarcane, sorghum, corn, barley, cassava, sugarbeets etc. Besides being a biomass based renewable fuel, ethanol has cleaner burning and higher octane rating than the various vegetable oils.

Gasohol (a mixture of 10% alcohol with 90% gasoline) is already a commercial fuel in over 35 countries of the World including the USA, Canada and France. In Brazil, cars with modified engines have been running for years on neat alcohol (Reeser et al, 1995).

In the United States, six major electric utility companies and a number of independent power producers are already using biofuels, while others are experimenting with crop types, fuel mixes and conversion and combustion technologies (Resource, 1996). The magnitude of energy needs in all developing countries provides an inexhaustible market for their total agricultural production at the highest possible level.

There are two possible approaches to using ethanol in a diesel engine. Firstly, the diesel could be injected in the normal way, with a carburettor added to atomize the ethanol, which has been stored in its own tank, into the engine's air stream. Secondly, the ethanol could be blended with diesel. The simplest way is to blend so that no engine modifications are required. In order to obtain blends of ethanol with diesel that are suitable for use as engine fuels requires a good knowledge of some basic fuel properties of such ethanol-diesel blends.

The objective of the work reported in this paper therefore was to study some basic fuel properties of local ethanol blended with diesel and compare these properties with those of diesel fuel alone.

MATERIALS AND METHODS

Six blends of diesel fuel with ethanol were used. They were obtained by mixing ethanol and diesel by volume in the following proportions:

I	=	5 percent ethanol and 95 percent diesel
II	=	10 percent ethanol and 90 percent diesel
III	=	15 percent ethanol and 85 percent diesel
IV	=	20 percent ethanol and 80 percent diesel
V	=	25 percent ethanol and 75 percent diesel
VI	=	30 percent ethanol and 70 percent diesel

Laboratory tests were then carried out using ASTM tests standards to determine the following properties; relative density, cloud and pour point, flash point, viscosity and calorific value.

The ethanol used for the research was obtained form the Ibadan Local market in Nigeria and it was made from sugarcane.

Relative density

This otherwise known as the specific gravity refers to the ratio of the density of a fuel to the density of water at the same temperature. With it other properties could be judged. The density of the fuels were measured by means of a capillary stopper relative density bottle of 20ml capacity.

Cloud and pour point

Cloud point is the temperature at which solidification of heavier components of fuels resulting in a cloud of crystals within the body of the fuel first appeared. While the temperature at which on further cooling of fuel, results in increased size and number of wax crystals and eventual coalescent of the fuel to form a rigid structure is termed pour point. The two temperatures are of importance in knowing the behaviour of fuels in a cold weather. They were determined using the Baskeyl Setapoint cloud and pour point apparatus (Texaco, Lagos1999).

Flash point

This is the minimum temperature at which the vapour given off by a fuel when heated will flash when a test flame is held above the surface without the fuel catching fire and its of importance when determining the fire hazard (temperature at which fuel will give off inflammable vapour). Flash point of the samples were measured by Pensky-Martens flash point closed apparatus of Texaco Apapa Installation, Lagos.

Viscosity Measurements

The resistance to flow exhibited by fuel blends, as expressed in various unit of viscosity, is a major factor of consequence in establishing their suitability for the mass transfer and metering requirements of engine operation. The coefficient of viscosity η is expressed as

$$\eta = \tau/S \qquad \text{........(1)}$$

where,

η = Dynamic (absolute) viscosity, Pa . s
τ = Shear stress, Pa
S = Shear rate, s^{-1}

The commonly used unit of centipose (cP) is equal to one mPa.s. A U-tube Saybolt viscometer was used for measurement of the dynamic viscosity of the samples at the Chemistry Department, University of Ibadan. The experiments were performed at 15^oC, 20, 26, 32, 38, 44 and 50^oC and the tests were replicated three times. The apparatus was based on the principle of measuring the time of gravity flow (in seconds) of the sample through a specified hole. The dynamic viscosity was calculated from the time by the following formula:

$$\eta = 0.073134dt - 5.94458d/t \qquad \text{...........(2)}$$

where,

η = Dynamic viscosity, cP
d = Density of sample, g/ml
t = Flow time, seconds

Calorific value

The calorific (heating) values of the blends were determined with the help of a Gallenkamp ballistic bomb calorimeter. A known amount of fuel was burnt in a bomb. The air was replaced by pure oxygen. The maximum deflection of the galvanometer on the control box was recorded after burning the samples. The effective heat capacity of the system was also determined using same procedure but with pure and dry benzoic acid as the test fuel. The calorific value was calculated as;

$$C.V. = \frac{(a_3 - a_1)Y}{Z} \qquad \text{...............(3)}$$

where,

C.V.	=	Calorific value of sample, kJ/kg
a_1	=	Galvanometer deflection without sample
a_3	=	Galvanometer deflection with sample
Y	=	Calibration constant
Z	=	Mass of fuel sample, g

The calibration constant (Y) is given as:

$$Y = \frac{6.32w_1}{a_2 - a_1} \qquad \text{………………..(4)}$$

where,

a_1 is as defined in equation (3)

W_1 = Mass of bensonic acid, g.

a_2 = Galvanometer deflection with benzoic acid.

Statistical analysis

In order to establish the significance difference of data recorded or computed, an analysis of variance was performed at 5 percent level of significance.

RESULTS AND DISCUSSION

Relative Density

The relative density of the fuels at different temperatures is shown in Table 1, while the percentage differences in the relative densities of the ethanol blends from diesel fuel is given in Table 2.

TABLE 1: Relative density of the fuels at different temperatures.

S/No	Ethanol	Diesel	15°C	20°C	26°C	32°C	38°C	44°C	50°C
1	0	100	0.8583	0.8485	0.8458	0.8442	0.8409	0.8390	0.8370
2	5	95	0.8414	0.8385	0.8365	0.8350	0.8308	0.8288	0.8258
3	10	90	0.8394	0.8351	0.8340	0.8330	0.8288	0.8268	0.8236
4	15	85	0.8382	0.8345	0.8318	0.8296	0.8268	0.8266	0.8228
5	20	80	0.8365	0.8342	0.8314	0.8289	0.8258	0.8241	0.8218
6	25	75	0.8357	0.8325	0.8266	0.8271	0.8238	0.8227	0.8198
-	30	70	0.8338	0.8320	0.8286	0.8269	0.8228	0.8217	0.8187

TABLE 2: Percentage differences from diesel

S/No	Fuel Type	15°C	20°C	26°C	32°C	38°C	44°C	50°C
1.	Diesel	-	-	-	-	-	-	-
2.	5% blend	1.97	1.18	1.10	1.09	1.20	1.21	1.35
3.	10% blend	2.20	1.58	1.40	1.33	1.44	1.45	1.60
4.	15% blend	2.34	1.65	1.66	1.73	1.68	1.48	1.70
5.	20% blend	2.54	1.68	1.70	1.81	1.80	1.78	1.82
6.	25% blend	2.63	1.88	1.88	2.02	2.03	1.94	2.05
7.	30% blend	2.85	1.94	2.03	2.05	2.15	2.06	2.19

It can be observed that as the percentage of ethanol in the blends was increased, the relative densities decreased. This is due to the fact that ethanol has lower density and as such will lower the density when mixed with diesel. It can also be seen that as the temperature increased, the relative densities decreased for all the fuels. These findings compare well with those earlier reported by Ali and Hanna (1996), Peterson et. al., (1986). When compared with diesel alone, at each temperature, the decrease in relative density as ethanol content was increased is more. From the analysis of variance, the observed differences at a particular temperature were not significant at 5% level of significance. However the differences were found to be significant as the temperature changes.

Flash point

The flash points of the fuels are given in Table 3.

TABLE 3: Flash, Pour and Cloud points of different blends

S/No	Sample %		Flash Point (°C)	Cloud Point (°C)	Pour Point (°C)
	Ethanol	Diesel			
1.	0	100	74	5	5
2.	5	95	24	5	-7
3.	10	90	25	5	-10
4.	15	85	27	5	-13
5.	20	80	25	5	-36
6.	25	75	25	5	-
7.	30	70	26	4	-

All the blends had a flash point that was 65% lower than diesel. The temperatures obtained were all below ambient room temperature of 27.5°C. Ethanol, which has a flash point below ambient when blended with diesel that flashed at a temperature of 74°C, vaporised and supplied the vapour that was ignited by the test flame. The flash Point gives the safe storage temperature for the blends.

The cloud and pour points for the fuels are also presented in Table 3. All the blends (except the 30%) were found to have the same cloud point with that of diesel. The reason is that all the blends have diesel as a major component. Diesel was reported to have a cloud point of 5°C while ethanol below 100°C (Stumpf, 1974), therefore the cloud point reached for all the blends was close to that of diesel.

The presence of ethanol in the blends however affected the pour point. Blends with 5,10, 15 and 20% ethanol were found to have pour point temperatures of –7, -10,-13 and –30°C respectively while pour points temperatures for blends with 25 and 30% ethanol content were not reached. These lower temperatures obtained for 5-20% ethanol content in the blends is due to the fact that ethanol delayed the degree of coalescent of the blends despite the high degree of miscibility of ethanol and diesel. But in the case of 25 and 30% ethanol content, phase separation of diesel and ethanol occurred. Diesel coalesced due to higher temperature coalescent, ethanol with very low temperature of coalescent did not coalesced till the minimum limit was reached. Hence the indeterminate values of blends with 25 and 30% ethanol content. Similar results have been reported (Goering et. al., 1982; Boruff et. al, 1982 and Kaufman et. al., 1982).

Viscosity

The viscosity of the fuels measured at seven (7) standard temperatures are as presented in Table 4.

TABLE 4: Viscosity of fuels at different temperatures

	Sample %		Viscosity (mPa.S) or (cP)						
S/No	Ethanol	Diesel	15^{o}C	20^{o}C	26^{o}C	32^{o}C	38^{o}C	44^{o}C	50^{o}C
1	0	100	6.24515	5.6114	4.6874	3.8003	3.4237	2.9008	2.8145
2	5	95	6.1597	5.5343	4.4934	3.6520	3.2788	2.7990	2.6366
3	10	90	5.9410	5.4564	4.2460	3.5599	3.2956	2.7395	2.5615
4	15	85	5.7471	5.1631	4.0045	3.4510	3.1396	2.6021	2.4691
5	20	80	5.6677	5.0587	3.8673	3.3708	2.7397	2.3921	2.1766
6	25	75	5.4957	5.0340	3.4395	2.8904	2.6027	2.2568	1.9198
7	30	70	5.3725	4.9171	3.0651	2.8040	2.4563	2.0782	1.8290

The measured viscosities decreased as the percentage of ethanol in the blends increased. The viscosities also decreased with increase in temperature. At 15^{o}C, the viscosities of 5, 10, 15, 20 and 25% blends were 1.4, 4.9, 8.0, 9.2 and 12% less than diesel respectively.

The 30% blend was 14% less viscous than diesel. The viscosities of the blends were however close to that of diesel when compared with other vegetable oils - diesel blend where their viscosities are usually very high (Varde, 1984, Msipa et. al., 1983; Bansal and Juneja, 1989). The reduction in the viscosity of the blends was mainly due to the presence of ethanol (with a very low viscosity) in the blends.

From the analysis of variance the differences in the viscosities were found to be significant at 5% level of significance. There was however no significant difference in the viscosity of 5 and 10% blends. The analysis also indicated that the effect of temperature variation on the viscosity was significant at 5% level of significance. These findings are in agreement with those reported by other researchers (Boruff et al., 1982; Ziejewski 1983; Ali and Hanna 1996).

Calorific Value

The calorific values of the tested fuels are shown in Table 5.

TABLE 5: Calorific value of the fuels

S/No	Ethanol	Diesel	Cal. Value kJ/kg	% difference to diesel
1.	0	100	44514.6	-
2.	5	95	43631.8	1.983
3.	10	90	43192.5	2.970
4.	15	85	42744.8	3.976
5.	20	80	41874.5	5.931
6.	25	75	41004.2	7.886
7.	30	70	40577.4	8.845

The calorific values for 5, 10, 15 and 20% blends were 2, 3, 4 and 6% respectively less than diesel while 25 and 30% blends were 8 and 9% respectively less than diesel. This indicates that the ethanol-diesel blends have over 90% of the calorific value of diesel. The calorific values decreased as the percentage of ethanol in the blends increased. When compared to other vegetable oils as reported by Bansal and Juneja (1989) and Masjuki et al., (1996), the calorific values of the tested fuels were quite high which explains why ethanol-diesel blends have better combustion characteristics than other vegetable oils – diesel blends. The results of the current study on calorific values are similar to the ones earlier reported (Peterson et. al., 1996; Ajav 1997).

CONCLUSIONS

The following conclusions could be drawn from the present study:

i. Relative density of all the blends were found to be lower than that of diesel fuel alone. The relative density was dependent on temperature
ii. Lower pour points were recorded for all the blends compared to 5^{o}C pour point obtained for diesel fuel alone. The cloud point was same for all the fuels tested.
iii. The viscosities of the 5, 10, 15, 20, 25 and 30% blends were 1.4, 4.9, 8.0, 9.2, 12 and 16% less than that of diesel respectively.
iv. All the blends were highly flammable with flash point temperature that was below the ambient temperature.
v. Calorific values of the blends were lower than that of diesel but the differences were not significant at 5% level of significance.
vi. In general, blends containing 5, 10, 15 and 20% ethanol have very close fuel properties compared to diesel fuel.

ACKNOWLEDGEMENT

The authors are grateful to the Management of Texaco Lagos for making some of their facilities available for part of this work. The Head, Department of Chemistry, University of Ibadan is also acknowledged for the permission to carry out the viscosity measurements in his department.

REFERENCES

Ajav, E. A (1997). Studies on the Use of Ethanol – Diesel Blends and Fumigated Ethanol in a Stationary Constant Speed Compression – Ignition engine. Unpublished Ph.D. Thesis Department of Farm Machinery and Power Engineering, G.B.P.U.A. & T, Pantnagar, India.

Ali, Y., and Hanna, M. A. (1996). Durability Testing of a Diesel Fuel: Methyl Tallowate; and Ethanol Blend in a Cummins N14-410 Diesel Engine, *Transactions, of the ASAE* Vol. 39(3). Pp 793-797.

Bansal, B., and Juneja, N. N. (1989). Performance Evaluation of Neem Oil as Diesel Engine Supplementary Fuel. *Proceeding of the 11th International Congress in Agric. Engineering* Vol. 4, pp 2551-1556.

Boruff, P. A., Schwab, A. W., Goering, C. E. and Pryde, E. H. (1982). Evaluation of Diesel Fuel-Ethanol Microemulsion. *Transactions, of the ASAE* Vol. 30 (3) pp 47-51.

Goering C. E., Schwab, A. W., Daugherty, M. J., Pryde, E. H., Heakin, A. J. (1982). Fuel Properties of Eleven Vegetable Oils, *Transaction of ASAE* Vol. 82 ppp. 1972-1477.

Kaufman, K. R., German, T. J., Derry, J. (1986). Field Evaluation of Sunflower Oil/Diesel Fuel Blends in Diesel Engine, *Transactions, of the ASAE* Vol. 29 (3) pp. 2-9.

Musjuki, H., Abdulmuin, M. Z. and Sii, H. S. (1996). Investigations on Palm oil Methly Esters in the Diesel Engine. Proc. Institution of Mech. Engrs. Part A: Journal of Power and Energy. 210:131-138.

Msipa, C. K. M., Goering, C. E. and Karcher, T. D. (1983). Vegetable oil Atomization in a D1 Diesel Engine. *Transactions of the ASAE*. 26(6): 1669-1672.

Peterson, C. L., Wagner, G. L. (1983). Vegetable Oil as Substitute for Diesel Fuel. *Transactions of ASAE*. Vol. 26(2): 322-327.

Peterson, C. and Reece, D. (1996). Emissions Characteristics of Ethyl and Methyl Ester of Reapessed Oil Compared with Low Sulphur Diesel Control Fuel in a Chasis Dynamometer Test of a Pickup Truck". *Transactions of the ASAE.* 39 (3): 805-816.

Reeser. L. G. Acra, A. P. L. and Lee, T. (1995). Covering Solar Energy into Liquid Fuels. Resource Engineering & Technology for a sustainable world. Published by ASAE,. 2(1): 8-11.

Resource, (1996). Biofuels Use in the United States. Published by ASAE. 3(3): 5

Shropshire, G. J. and Goering, C. E. (1982). Ethanol Injection into a Diesel Engine". *Transactions of the ASAE.* 25(3): 570-575.

Schlautman. N. J., Schinstock, J. L. and Hanna, M. A. (1986). Unrefined Expelled Soyabean Oil Performance in a Diesel Engine. *Transactions of the ASAE* Vol. 29(1): 70-73.

Stumpf, U. E. (1974). Alcohol programme in Brazil. Energy in the Developing World (The Real Energy Crisis) edited by Vaclav, S.; Knowland, W. E. pp. 259-264.

Texaco (1999). Texaco Apapa Installation Lagos Laboratory Manual for analysis. Lagos.

Varde. K. S. (1984). Soy Oil Sprays and Effects on Engine Performance. *Transactions of the ASAE*. 27 (2): 326-330, 336.

Yahya, R. K.; and Goering, C. E. (1977). Some Trends in Fifty-five years of Nebraska tractor Test Data. ASAE paper No MC-77-503, ASAE, St. Joseph, Ml 49085.

Ziejewski, M. (1983). Vegetable Oils as a Potential Alternative Fuel in a D. I. Engines. SAE Paper No. 831359. Society of Automotive Engineers, Warrendale, PA.