Emission of Elsbett Engine Using Palm Oil Fuel

T S Tang*, Hj Ahmad Hitam * and Yusof Basiron*

ABSTRACT

The emission from exhaust of motor vehicles is a major source of air pollution. As the chemical composition of palm oil differs from that of diesel fuel, it is expected that the composition and characteristics of the emissions from the combustion of these two fuels shall differ. Recent monitoring of the emission from the exhaust had shown that operating the multifuel Elsbett engine with palm oil resulted in an improvement when compared with that when operating on diesel fuel under identical conditions.

There were reductions in 29.70% of hydrocarbons, 7.6% of nitrogen oxides, and 47.2% in particles. Similarly there was also significant reduction in the emission of benzene, toluene, ethyl-benzene and xylene when diesel was replaced by palm oil as fuel. There were however slight increases in carbon monoxide (by 2.4%), carbon dioxide (by 1.2%) and also fuel consumption (by 7.0%). In terms of smoke characteristics, there were distinct improvements in the BOSCH smoke number (by 29-61%) and opacity (by 45-86%) in the range of engine operating speeds from 1845 to 4100 rpm.

INTRODUCTION

The burning of fuel gives rise to energy, but also releases smoke particulates and various combustion gases which pollute the air. Emission from motor vehicle is the major source of air pollution today. This is especially evident in populated urban cities where such pollution often results in smog. Exhaust gases from automobiles using fossil fuels contain various kinds of harmful pollutants such as carbon monoxide, hydrocarbons, nitrogen oxides, sulphur oxides, aromatic hydrocarbons and smoke particulates. *Figure 1* illustrates that mobile sources (mainly motor vehicles) contributed to about 60% in 1987-1988, 80% in 1989-1992, of the air pollution in Malaysia (DOE 1993). In view of the foregoing, the research into the development of new sources of fuel as alternatives to fossil fuel is directed to developing one which is not only readily renewable but also environmentally friendly. Agricultural products such as vegetable oils are considered favourable substitutes as combustion of biomass constitutes a closed system as far as environmental impact is concerned because the carbon dioxide released is used by the plant in the photosynthetic process. The virtual absence of sulphur in vegetable oil offers yet another advantage as there will be no emission of sulphur dioxide in the exhaust.

In the PORIM research on the feasibility of palm oil as a renewable source of fuel in the multifuel Elsbett engine fitted to Mercedes cars, the measurement of the characteristics and composition of the emission from the exhaust forms an important aspect of the evaluation. For this purpose, PORIM sought the expertise assistance from the Technical University of Munich and the TUV Bayern Sachsen, Germany for this measurement. The scope of testing included, amongst others, the following:

i) The exhaust gas components such as carbon monoxide (CO), carbon dioxides (CO_2), benzene, toluene, xylene and ethyl benzene as well as the particulate emission.
ii) A comparison of the blackening rates according to Bosch (in terms of Bosch smoke number,BSN) and of exhaust gas opacity.
iii) Influence of fuel on the engine power and fuel consumption.

METHODOLOGY

Engine Used

The test was carried out on a production car, Mercedes Benz 190, with its engine being replaced by that of Elsbett Engine. This 64kW rated output power at 4300 rpm multifuel, three-cylinder, Elsbett engine was equipped with a turbocharger and an intercooler. The engine had a compression ratio of 18:1 and a displacement of 1456 cm^3. The Elsbett engine is a compression ignited, intermittent-combustion direct injection diesel engine.

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*Palm Oil Research Inst. Of Malaysia (PORIM)

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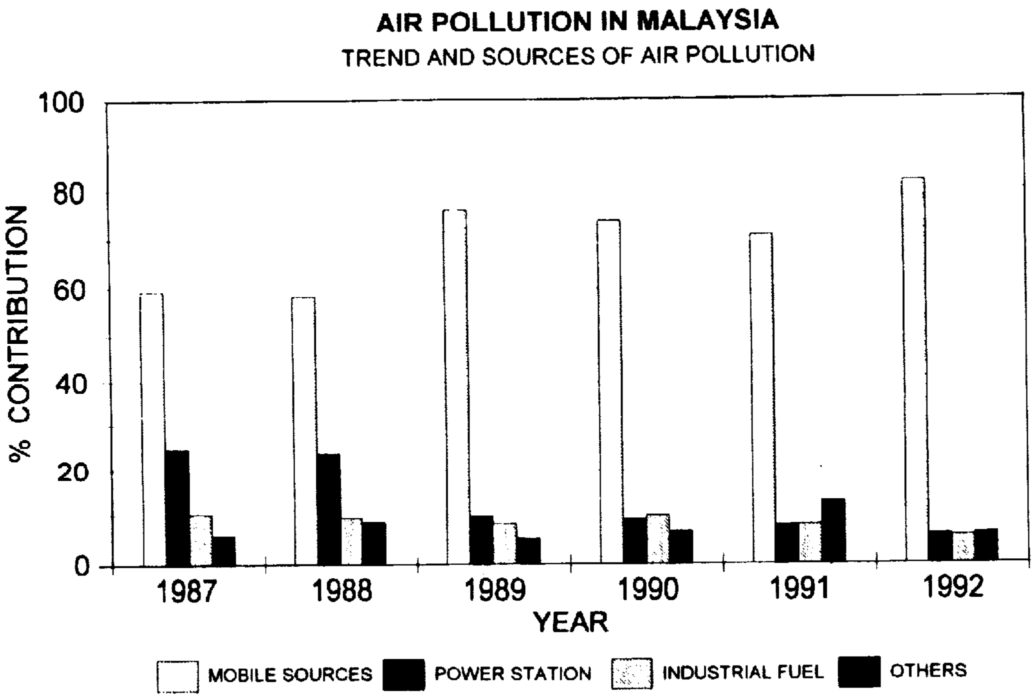

Figure 1. Levels and sources of air pollution in Malaysia from 1987-1992.

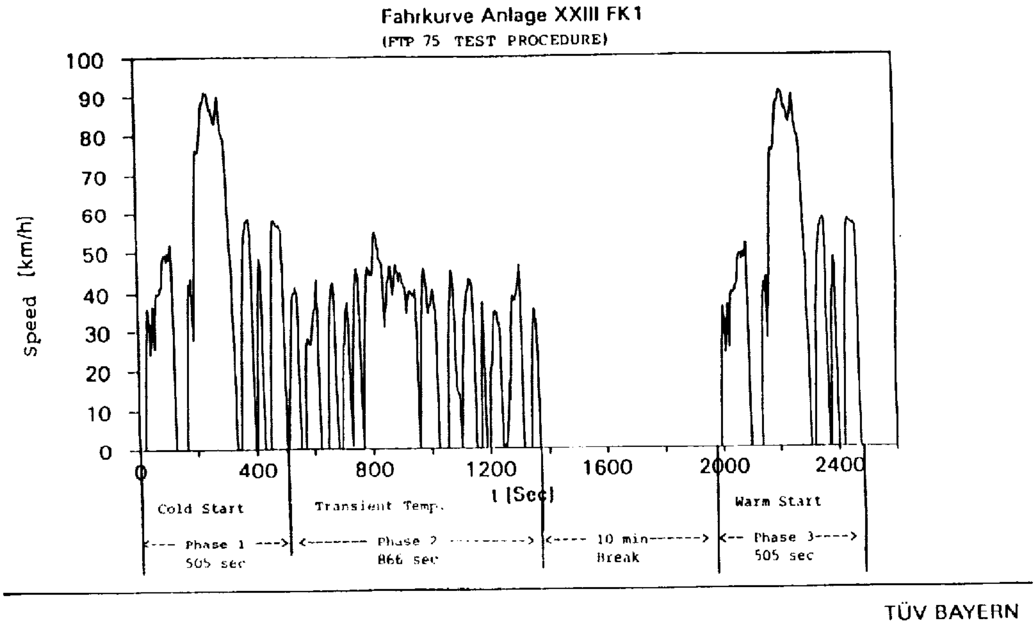

Figure 2. Drive pattern for fuel emission test according to FTP 75 procedure.

Throughout the trial, the settings of the engine were selected to optimize the use of vegetable oil as fuel.

Engine operating pattern for test

The test was carried out on a chassis dynamometer with electrical eddy-current brake and inertia-weight set. The power and the speed could be set up to 200 kW and 200 km/h respectively.

The driving pattern as shown in *Figure 2* served as a comparative procedure. The driving underwent three phases *i.e.* 'cold start', 'transient temperature' and 'hot start'. All these phases represented the handling characteristics in urban, overland and motorway traffic.

The driving wheels of the vehicle were positioned on the rolls of the chassis dynamometers during the test. The driver operated the vehicle in accordance to the test procedure preset on a computer monitor. The drive had to follow all the acceleration, constant and deceleration driving conditions as preset from the starting to the stopping of the engine. The monitor also showed the tolerances to which the driver had to comply. A cooling blower was arranged in front of the vehicle to simulate resistance and cooling was normally provided by the airstream.

Fuels Used

For this study, the two fuels compared were diesel and palm oil. Diesel is a broad class of petroleum products obtained from the distillation of crude fossil oil whereas palm oil is the oil extracted from the mesocarp of the fruits of the palm, *Elaeis guineensis*. Chemically, diesel consists mainly of hydrocarbons, but palm oil, like other vegetable oils and fats, consists mainly of triglycerides whose molecules contain approximately 72.30% carbon, 11.30% oxygen and 16.4% hydrogen.

Table 1 shows the relevant data on the various characteristics of the fuels, *i.e.* diesel and palm oil used in the study. The main differences between the two are:

i) Palm oil is high boiling, thus a pre-heater is installed in the engine.
ii) Palm oil has practically no sulphur whereas the sulphur content of diesel is about 0.3%.

Exhaust-Emission Test

The exhaust gases were analysed by using the CVS-method (constant volume sampling) with a positive displacement pump (PAP) in accordance with the requirement of a amended version of 93/59/EEC schedule III, Annex 5 and ECG-R 83 (1992). The complete set of the test system consisted of the following (*Figure 3*):

i) Dilution Tunnel
In this tunnel, exhaust emission from the Elsbett engine was diluted with ambient air homogeneously. From this tunnel, there were several tubings to divert a constant flow of the diluted exhaust gas to the various analyzers and gas sampling devices.
ii) Analyzer System - HORIBA, Type MEXA 8420

This comprised:

- The analyzers for the exhaust pollutant gases - hydrocarbons, carbon monoxide, carbon dioxide and nitrogen oxides,
- particle-filter admission and particle filter weighing
- BOSCH filter set-up for Smoke Number
- Hartridge equipment for opacity (ECE-R24) by comparing the absorption of light of the exhaust gas in a certain path length in relation to that of ambient air.

iii) Engine power measuring system in accordance with the requirement of DIN 70020 (1976).
iv) Fuel consumption monitoring system in accordance with the requirement of DIN 70030 (1978).
v) A computer system which could provide fully automatic computation and reporting.

Analysis of BTX Aromatic Hydrocarbon

From the exhaust, a known volume of the raw (undiluted) emission was sucked from the collection hose *via* two small activated carbon tubes (ACTIVKOHLE, Rochrchen, Germany) connected in series. Subsequently the component gases, amongst them benzene, toluene, ethyl-benzene and xylene were desorbed from the activated carbon tubes and were analysed by capillary gas chromatography.

TABLE 1 . FUEL CHARACTERISTICS OF DIESEL AND PALM OIL

CHARACTERISTICS	DIESEL FUEL	PALM OIL	ASTM STD
Cetane Number	49 - 53	52	D 613
Density at 15 C kg/l	0.835 - 0.845	0.9153	D 1298
Boiling range :			
-50 % C	min. 245	335	D 86
-90 % C	min. 320	352	
C	max. 340		
End of boiling C	max. 370	352	
Flash point C	min. 55	266	D 93
CFPP C	min. -	+17	EN 116
	max. -5		
Viscosity at 40 C mm /s	min. 2.5	40.85	D 445
	max. 3.5		
Sulfur content %i.w.	min. -	0.044	D 1266
	max. 0.3		D 2622
			D 2785
Copper-fin corrosion	max. 1	1a	D 130
Conradson carbon residue (residue 10%) %i.w.	max. 0.2	7.15	D 189
Ash content %i.w.	max. 0.01	< 0.01	D 482
Water content %i.w.	max. 0.05	0.037	D 95
			D1744
Acid number (strong acid) mg KOH/ g	max. 0.20	0	
Oxidation stability mg/100ml	max. 2.5	0.1	D 2274

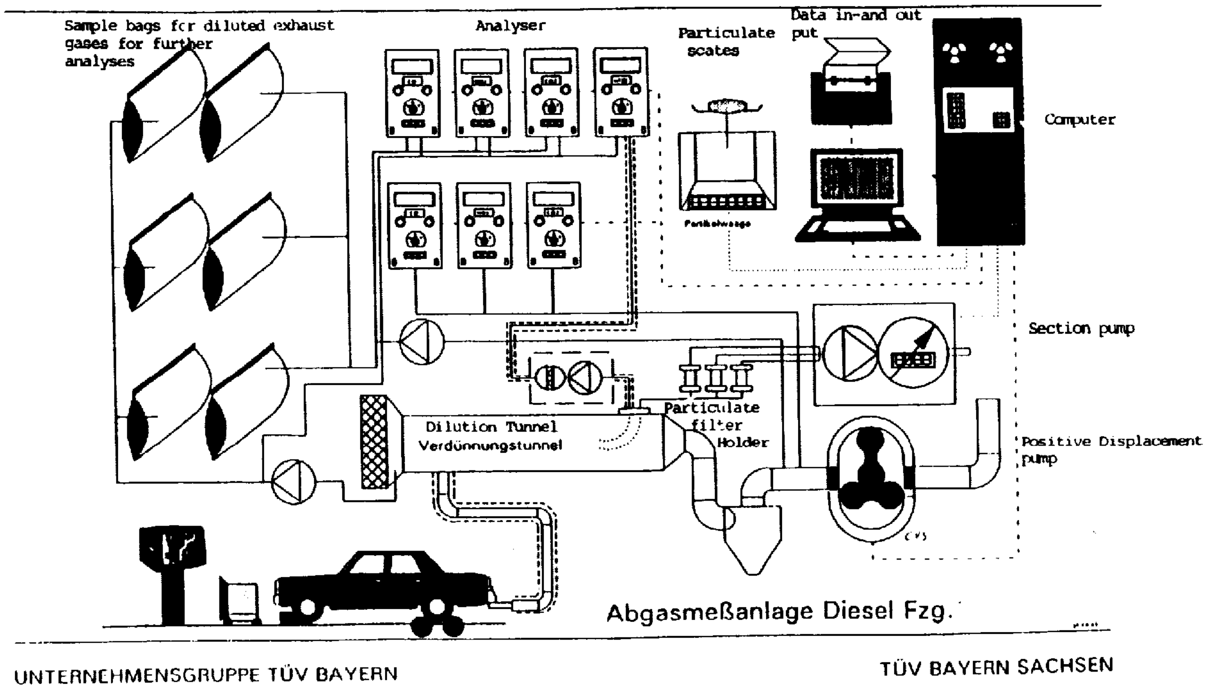

Figure 3. Flow chart of testing and sampling system used in the fuel emission test

RESULTS

During the monitoring of the exhaust emission, the driving pattern was kept identical for two fuels compared (*i.e.* diesel and palm oil). The settings of the engines were also kept the same.

Effect of Fuels on Engine Power and Fuel Consumption

Figure 4 shows that the power of the engine depended on the driving speed. When diesel was used, a maximum power of 63kW was attained when the engine was operating at 4100 rpm, whereas, in the case of palm oil fuel, the maximum power achieved was 52kW at the engine speed of 4200 rpm. Thus, the engine power was lower by about 17.5% when diesel was replaced with palm oil. This could be attributed to the lower energy content of palm oil which is about 39.0 MJ/kg compared to that of 45.8 MJ/kg for diesel (Yusof, *et al.*, 1994). Our study also showed that fuel consumption was higher by 7.0% when palm oil was used instead of diesel, in the Elsbett engine. This was also because generally vegetable oil has lower energy content compared to diesel fuel.

However in a separate study, PORIM researchers had shown that in a Mercedes 190D fitted with the Elsbett 1.45 litre three-cylinder engine of power capacity of 60 kW, the consumption of palm oil fuel was about 6 to 7 litres per 100 km, whereas in a Mercedes 250D fitted with a conventional diesel engine of power output of 60 to 75 kW, the diesel consumption was about 9 litres per 100 km. This means the Elsbett engine being smaller in displacement capacity but of similar power utilized less fuel compared to the conventional diesel engine (Yusof, *et al.*, 1992).

Effect of Fuels on Emission Composition

The compositions of exhaust emission from the Elsbett Engine when using diesel and palm oil as fuels under the identical pre-programme drive patterns are given in *Table 2*. The particulate content of the exhaust as well as the fuel consumptions are also given. *Figure 5* is a graphical representation of these data and it provides a clearer comparison. The contents of hydrocarbons, carbon monoxide, nitrogen oxides, carbon dioxide and particulate of the exhaust from diesel were 0.128, 0.815, 1.12, 146.52 and 0.142 g/km respectively. Whereas, those measured for palm oil fuel were 0.09, 0.835, 1.035, 148.28 and 0.075 g/km respectively.

Thus comparing the two sets of data, (*Figure 6*) it is clear that using palm oil as fuel resulted in the favourable reduction of discharge of hydrocarbons by 29.70%, nitrogen oxides by 7.59% and particulate by 47.2%. However, in terms of carbon monoxide and carbon dioxide, there were marginal increases of 2.45% and 1.20% respectively.

Environmentalists are also very concerned about the emission of benzene, toluene, ethyl-benzene and xylene (BTX) from exhaust of motor vehicles. This could be seen from recent reports, originating from the United Kingdom that in the emission from motor vehicles using unleaded petrol, there were significant levels of benzene (CAP 1994). Thus it is only sensible that the content of the BTX gases were monitored in our study also. In the monitoring of BTX gases, the measurements were carried out on samples taken at each of the three phases of the drive cycle, ('cold start', transitional and 'hot start') as shown in *Figure 2*. The data obtained are given in *Table 3* which show that in all the measurements, exhaust gas from the engine when palm oil was used resulted in lower emission of benzene, toluene, ethyl-benzene as well as xylene. The reductions were in the range of 6.6 to 15.8% for benzene, 6.6 to 56.2% for toluene, 33.5 to 59.0% for ethylbezene and 64.1 to 76.4% for xylene. These significant reductions are shown more vividly in the bar chart in *Figure 7*. When the results for each of the three phases of the tests for diesel and palm oil as fuels were examined, it could be generally observed that the emission of BTX gases were higher during the 'cold start' (phase 1) and decreased when the engine warmed up at the transition state (phase 2). The corresponding data for the 'hot start' (phase 3) after the 10 min. break were about the same or slightly lower than those recorded for the transition phase (phase 2). These trends indicated that during the 'cold start', the engine was not running at the optimum state, thus the fuel combustion had not reached its maximum efficiency. When the engine had warmed up, as in the transition phase, efficiency of fuel combustion improved, thus resulting in the reduction of BTX gases. Similarly, during 'hot start', combustion of fuel in the engine was more efficient when compared to 'cold start'.

TABLE 2. CONTENT OF COMMON EMISSION GASES FROM ELSBETT ENGINE USING DIESEL AND PALM OIL AS FUELS

EMISSION GASES (g/km)	DIESEL FUEL	PALM OIL	DEVIATION OF PALM OIL FROM DIESEL %
HYDROCARBONS (HC)	0.13	0.09	-29.70
CARBON MONOXIDE (CO)	0.82	0.84	2.45
NITROGEN OXIDES (NOX)	1.12	1.04	-7.59
CARBON DIOXIDE (CO2)	1.47	1.48	1.20
PARTICULATES	0.14	0.08	-47.20
FUEL CONSUMPTION (l / 100 km)	5.58	5.97	7.00

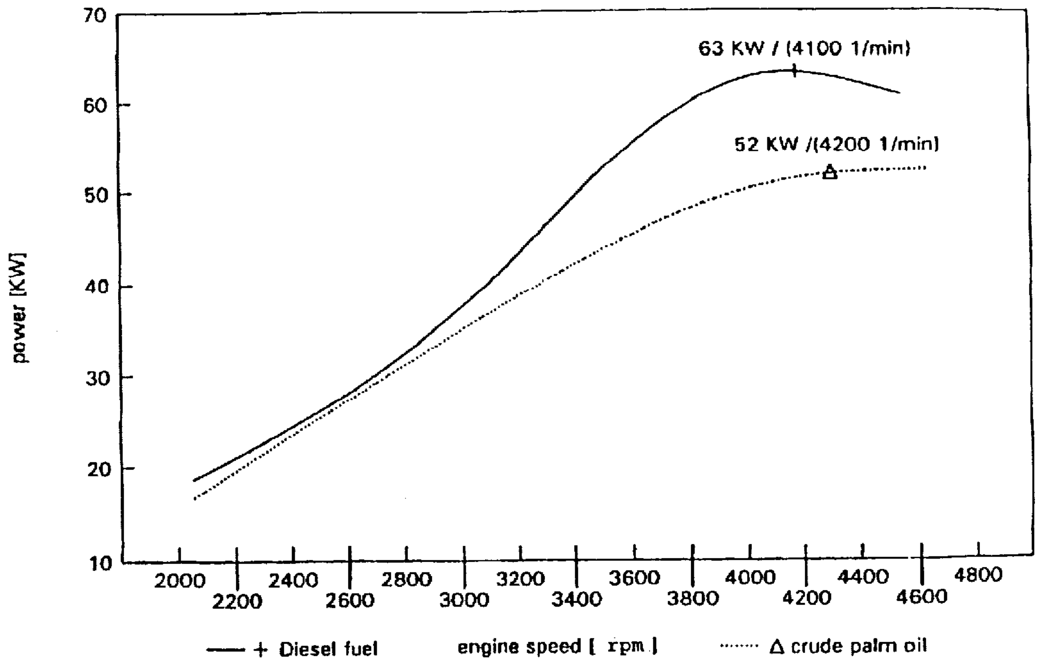

Figure 4. Comparison of Elsbett engine power using diesel and palm oil as fuels

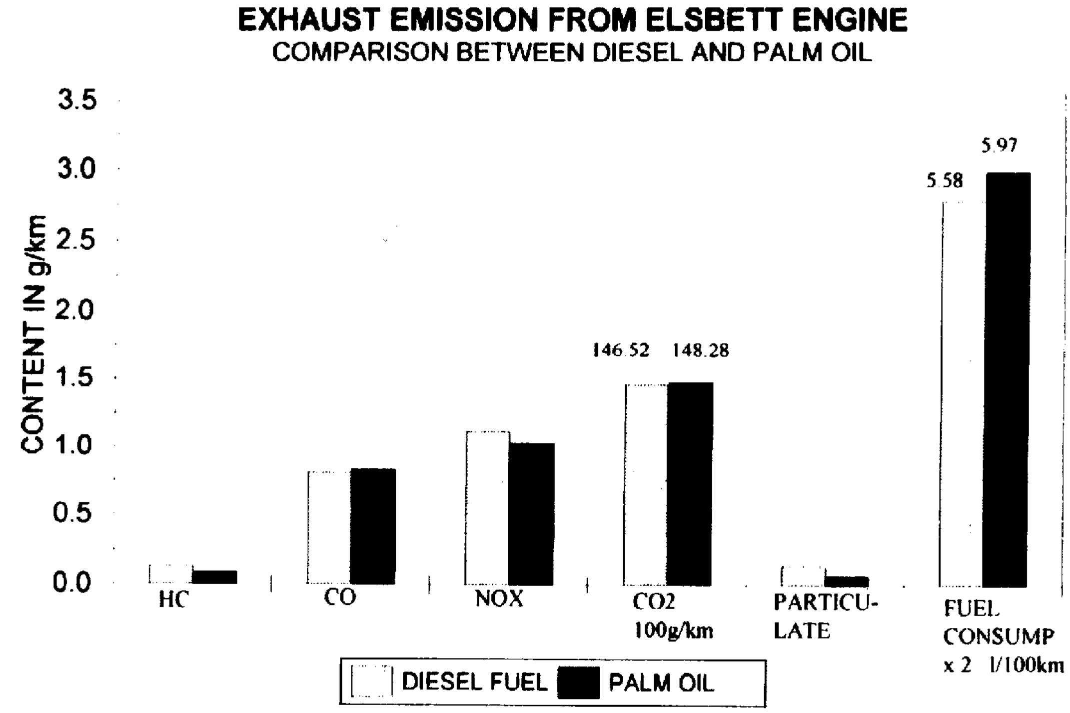

Figure 5. HC, CO, NO_x, CO_2, particulate emission and fuel consumption using diesel and palm oil and fuels

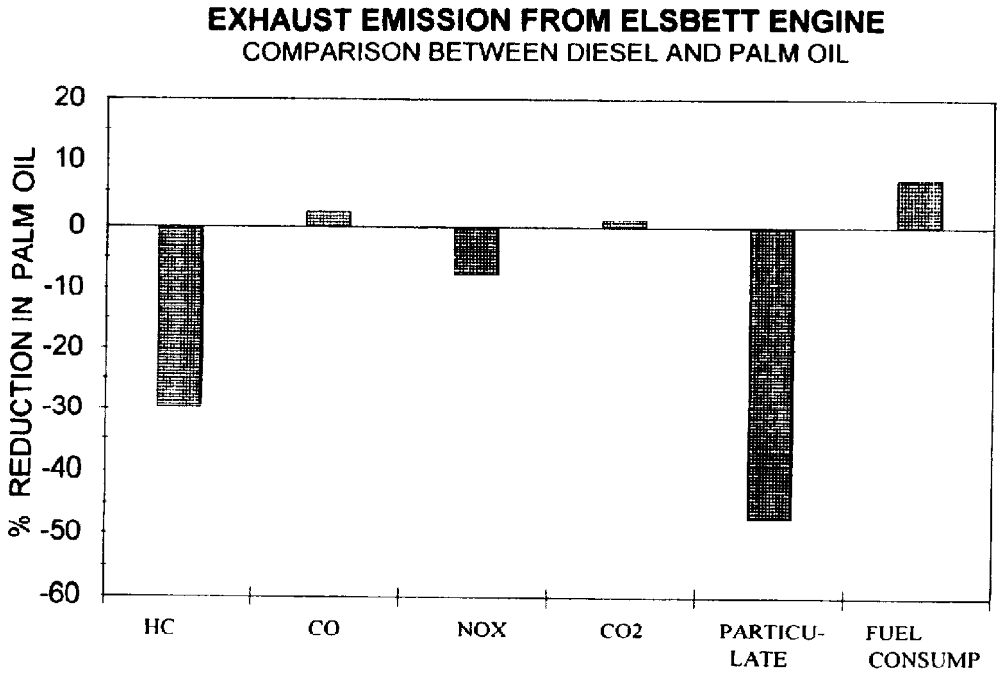

Figure 6. Comparison of exhaust gas composition, particulate emission and fuel consumption using diesel and palm oil as fuels.
(Reduction in palm oil '-ve' values; Increase in palm oil - '+ve' value)

TABLE 3. EMISSION OF BTX FROM ELSBETT ENGINE USING DIESEL AND PALM OIL AS FUELS

EMISSION GASES mg/m^3		DIESEL FUEL	PALM OIL	DEVIATION OF PALM OIL FROM DIESEL %
BENZENE	Phase 1	3.05	2.850	-6.6
	Phase 2	1.90	1.750	-7.9
	Phase 3	1.90	1.600	-15.8
TOLUENE	Phase 1	0.685	0.640	-6.6
	Phase 2	0.685	0.300	-56.2
	Phase 3	0.615	0.285	-53.7
ETHYL BENZENE	Phase 1	0.195	0.080	-59.0
	Phase 2	0.100	0.050	-50.1
	Phase 3	0.075	0.050	-33.5
XYLENE	Phase 1	0.835	0.300	-64.1
	Phase 2	0.395	0.105	-73.4
	Phase 3	0.345	0.085	-76.4

TABLE 4. BOSCH SMOKE NUMBER (BSN) OF EXHAUST EMISION FROM ELSBETT ENGINE USING DIESEL AND PALM OIL AS FUELS

SPEED rpm	DIESEL FUEL	PALM OIL	DEVIATION OF PALM OIL FROM DIESEL
1845	5.1	3.6	-29.7
2296	6.2	4.2	-32.3
2747	5.7	2.8	-50.9
3198	5.7	2.2	-61.4
3649	5.0	2.0	-60.0
4100	4.8	1.9	-60.4

TABLE 5. OPACITY OF EXHAUST EMISSION FROM ELSBETT ENGINE USING DIESEL AND PALM OIL AS FUELS

SPEED rpm	DIESEL FUEL	PALM OIL	DEVIATION OF PALM OIL FROM DIESEL %
1845	1.3	0.55	-57.7
2296	1.9	1.05	-44.7
2747	1.9	0.60	-68.4
3198	2.1	0.30	-85.7
3649	1.4	0.20	-85.7
4100	1.4	0.20	-85.7

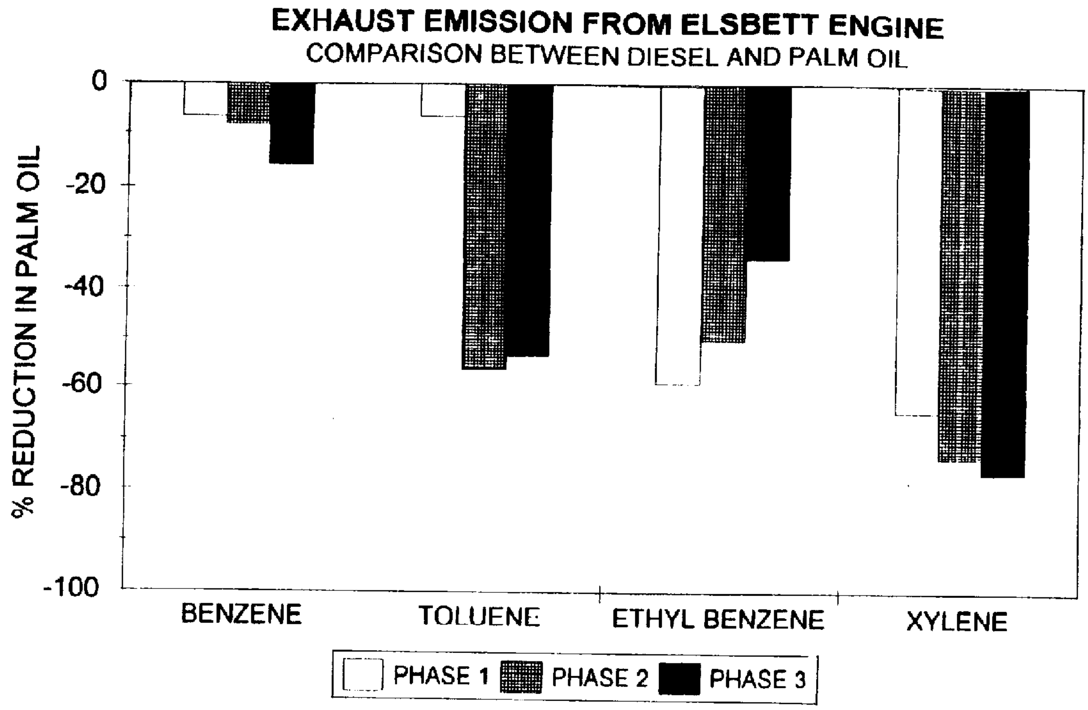

Figure 7. Comparison of aromatic hydrocarbons in emission using diesel and palm oil as fuels (Reduction in palm oil - '-ve' values)

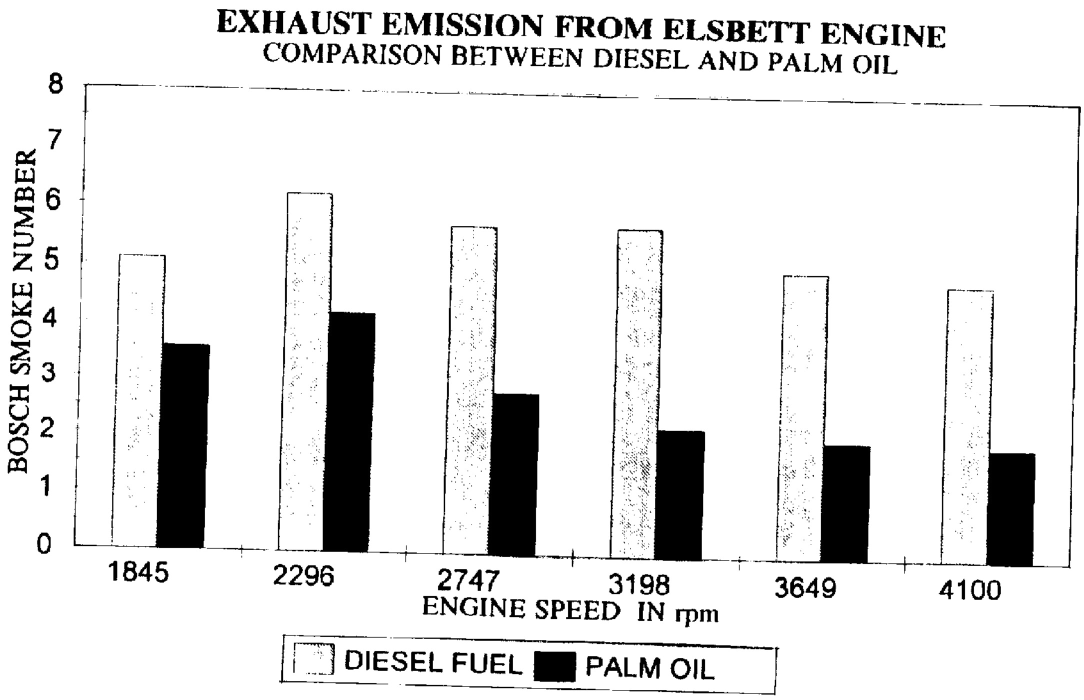

Figure 8. Bosch smoke number (BSN) of emission using diesel and palm as fuel

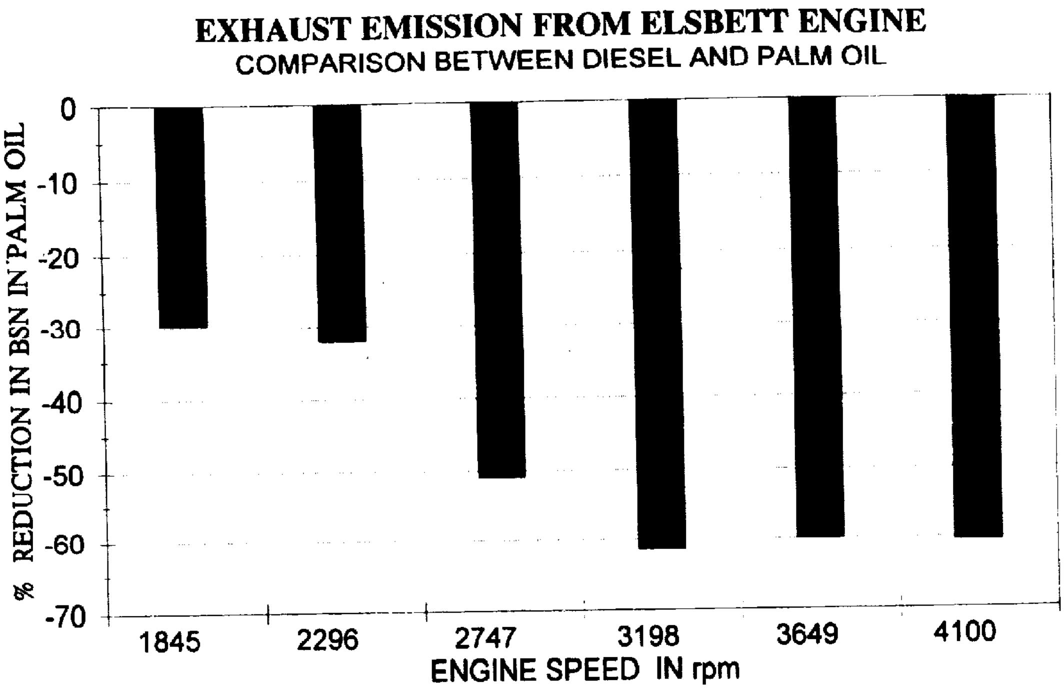

Figure 9. Comparison of Bosch Smoke Number (BSN) of emission using diesel and palm oil as fuel. (Reduction in palm oil - '-ve' valve)

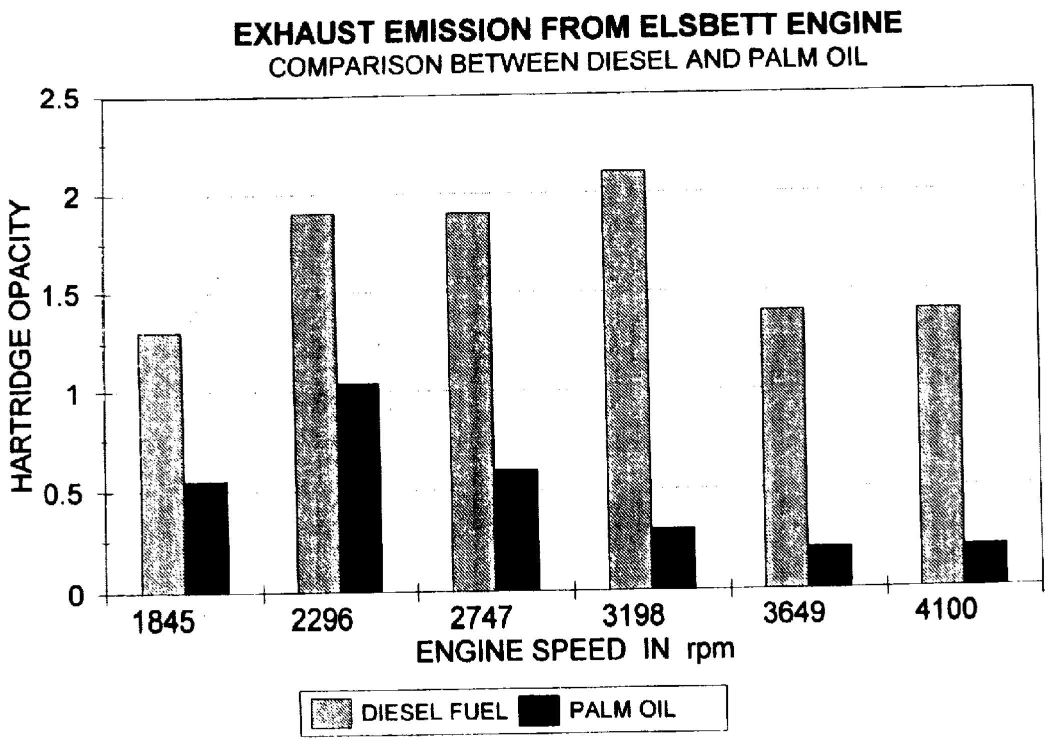

Figure 10. Hartridge opacity of emission diesel and palm oil as fuels

Effect of fuels on smoke characteristics

The BOSCH smoke number (BSN) of the exhaust from diesel and palm oil fuels were recorded in *Table 4*. The parameter was measured at different engine speeds. In all measurements carried out, it was observed that the BSN of palm oil fuel was lower by 29.4 to 61.4% when compared to those of diesel fuel *Figure 7*. This means that the exhaust gas from the Elsbett engine when using palm oil fuel was not as dark as that when diesel was used. There was much less 'blackening' of the exhaust gas with palm oil fuel.

The opacity of the exhaust gas is also related to the blackening effect of the fuel; the darker the exhaust, the more light it will absorb over a certain defined length. *Table 5* gives the opacity, according to the Hartridge measuring equipment. Again the data show that the emission from the engine using palm oil absorbed less light, by as much as 44.7 to 85.7% when compared to diesel (*Figure 8*), indicating a higher level of light transmission.

DISCUSSION

In most of the measurements on various pollution parameters namely, component gases (hydrocarbons, nitrogen oxides, particulate, BTX), BOSCH number and Hartridge Opacity, the results were more favourable with palm oil when compared to diesel. Only the contents of carbon monoxide and carbon dioxide were marginally higher. Thus one can conclude that these data confirm the claim that palm oil is generally a more environmentally friendly fuel compared to diesel. This is certainly a plus point in the development of biofuel from vegetable oil. Similar studies carried out by Zilmas (1993) had also shown that comparison of the exhaust from other engines using diesel and rape oil/rape methyl esters followed similar trends. At the moment vegetable oil as a commercial fuel is still far away from reality because of present high price and also there is still a ready market in food and oleochemical applications. However in time to come, when consumer demands a cleaner environment, coupled with diminishing supply of fossil fuels, it is inevitable that mankind will have to rely on other alternatives to supplement the shortages and palm oil would be an obvious choice as far as Malaysia is concerned.

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REFERENCE

CAP (1994). Utusan Konsumer, Nov. 1994, p 1-3 Consumer Assoc. of Penang.

DIN 70020 (1976). German Standard. DIN 70020 Part 6 Nov. 1976. Automotive Industry : Performance Services.

DIN 70030 (1978). German Standard. DIN 70030 Part 1, July 1978. Determination of the Fuel Consumption of Motor Vehicles, Passenger Cars.

DOE (1993). Annual Report of Dept. of Environment Ministry of Science and the Environment, Malaysia.

ECE-R24 Schedule 8 - Properties of Smoke Measuring Units (Opacimeters) and Schedule 9 - Structure and Use of Smoke Measuring unit (Opacimeter).

ECG-R83 (1992). Uniform Vehicle Approval Conditions with respect to Engine Pollutant Emission in Accordance with the Fuel Requirements of the Engine - (Including Amendment 01 of Dec. 30, 1992 and Adjustment 1 of Sept. 11, 1992).

YUSOF, B and AHMAD, H (1992). Cost Effectiveness of the CPO fuel in the Mercedes Elsbett engine car. PORIM Information Series No. 4. July, 1992.

YUSOF, B, MA, A N, CHOO, Y M and AHMAD, H (1994). Palm Oil - A renewable Biofuel for Urban Transport. Paper presented at Seminar or Urban Transport, Apr. 22, 1994. Kuala Lumpur.

ZILMAS, R (1994) Rape Oil and Rape Methylesters-Fuels for the Future? - Private Communication.