Biofuel: Impact on Environment

Husna Kassim*, Mariani Osman* and Hamzah Abdul Hamid*

SUMMARY

The paper focuses on the issue of reducing tailpipe emissions through the use of biofuels. Considerations central to the selection of biofuel against other alternative fuels for automotive use are also highlighted. The paper briefly compares emissions data available on crude palm oil methyl ester from a study conducted at PRRS.

INTRODUCTION

The goals of economic development for Malaysia are enshrined in the "vision 2020" which envisages the country reaching the status of a developed nation by the year 2020. Industrialisation will be a key factor towards achieving this goal. The major thrust of the National Development Policy (Yusof Ismail, 1993) is to attain balanced development and one critical aspect is to ensure that in pursuit of economic development, adequate attention be given to the protection of the environment so as to maintain long-term sustainability of the country's development. Like other industrialised nations, Malaysia is beginning to experience the problems of industrialisation and with it, problem of the growing traffic.

The onslaught of the environment by vehicular emissions, industrial processing wastes, solid wastes and fuel combustion emissions from stationary sources such as power plants and furnaces is a growing concern. Major pollutants in urban air include lead, carbon monoxide, volatile organic compounds, nitrogen oxides, sulphur oxides and particulates. According to a RM 10 million study on air pollution by the Japan International Cooperation Agency (JICA) conducted in 1993, 70% of urban air pollution in Peninsular Malaysia is contributed by motor vehicles emissions (Business Times, 28/9/94). Understandably, irritation from fumes and odours from vehicular emissions remains a major public concern particularly in the urban centres of Kuala Lumpur, Shah Alam and Petaling Jaya of the Klang Valley.

Over 630,000 tonnes of pollutants were pumped into the atmosphere of the Klang Valley by mobile sources in 1990 alone according to figures in *Figure* 1. Motor vehicles (lorries, taxis, buses, motorcycles and passenger cars) are concentrated in the urban areas of Peninsula and East Malaysia. *Table 1* shows the cumulative number of vehicles registered in Malaysia with over 6 million petrol vehicles and under 1 million diesel vehicles, which makes up the majority of commercial vehicles. Given the enormous potential for future global growth in the automotive industry, particularly in Asia, it is estimated that the total number of cars will be over 600 million by the year 2010 (Paramins Post, September 1994). Obviously this will result in a corresponding increase in the total amount of emissions, unless positive steps are taken globally to curtail them.

DEVELOPMENT IN VEHICULAR EMISSION REDUCTIONS

There are four general approaches to reduce motor vehicle emissions:

1) technological improvements and modifications to the vehicle
2) use of fuels that reduce mass emissions and less reactive emissions in the atmosphere
3) inspection and maintenance programmes
4) transportation control measures

The transport and manufacturing sectors together consume more than 70% of the country's energy needs (Yusof Ismail, 1993). It would be therefore sensible to increase energy efficiency measures targeted at these two sectors. Properly formulated policies which reward energy efficiency and penalise the less efficient will go a long way. In transportation, improvement in mass/public transport systems, and review of policy towards private car ownership could be an effective means of reducing vehicular emissions. Reduction of mass emissions through use of clean alternative fuels or reformulated fuels seems to be an immediate answer to pollution control.

Although reductions in automotive emissions during the past 25 years have resulted primarily from the implementation of control technology, two important fuel modifications were also enacted. In the early 1970's, the removal of lead from gasoline in USA was begun with the

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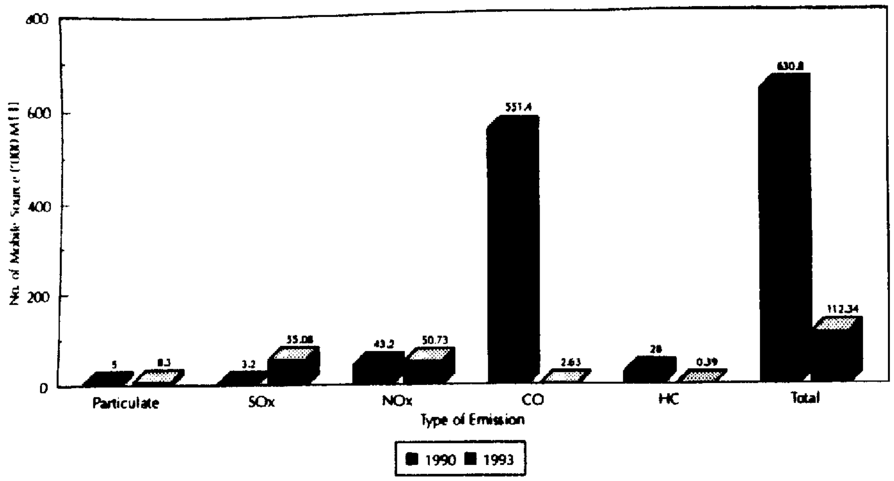
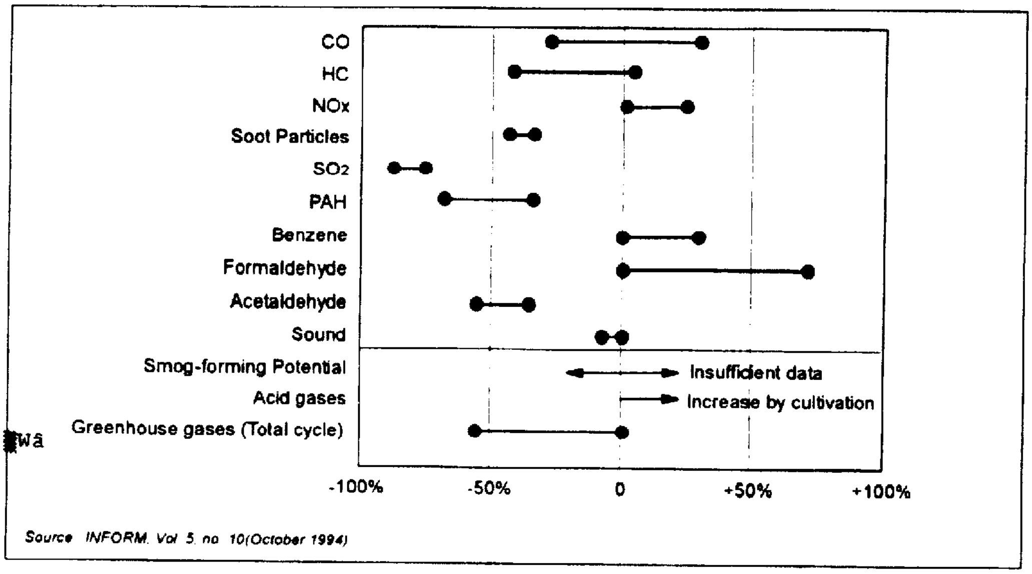


Figure 1. Emission of polutants to the atmosphere by mobile sources ('000 MTT) , 1990, 1993



Source INFORM. Vol 5. no 10(October 1994)

Figure 2. Proportional changes in emission in g/km

required sale of unleaded gasoline nationally to meet the needs of catalyst-equipped cars. Limitation on fuel vapour pressure has recently helped control evaporative emissions. The next phase of fuel changes to reduce emissions follows two separate approaches;

1) alternative fuels and
2) reformulated gasolines

In 1985, the Malaysian Government had taken several steps to reduce air-borne lead through reduction of lead content in motor gasoline. This was coordinated by Department of Environment (DOE) and implemented as follows: prior to 1985 lead content was 0.8 g/l; then from July 1985, it was 0.4 g/l; and from January 1990, it was further reduced to 0.15 g/l. To further reduce air-borne-lead, unleaded gasoline was first introduced in the Malaysian market in July 1990. It is estimated that Malaysia will go totally unleaded by middle 1996 with the legislated requirement of the 3-way catalytic converter for all new cars so that all harmful gases will be converted to carbon dioxide, nitrogen and water.

CHOICE BETWEEN FUELS

The introduction and expanded use of alternative or clean fuels such as natural gas, liquid petroleum gas and alcohols have been proposed as part of the strategy to reduce automotive emissions in USA. Natural gas is a very competitive alternative not only for its environmental advantages but because of its domestic abundance, superior safety, and low cost. To help establish a stronghold for natural gas, the gas industry must assume the responsibility for thoroughly understanding emissions regulations so that realistic goals may be set and achieved to make NGV competitive. How do we pick an alternative fuel then? What are the factors or considerations essential to a sensible choice? Is it the cost (cost of fuel, infrastructure, maintenance, vehicles, or cost of public education)? Be it the supply, safety, regulatory compliance, preference or prejudice or vehicle performance, they all play an important role in determining the choice fuel.

REFORMULATED FUELS

The relatively low cost of gasoline and diesel fuel has combined with their high power density, good on-board storage capacity, established infrastructure and public acceptance, to create a great resistance to changing to alternative fuels until supplies really do dry up. The area where these two conventional fuels compare less favourably with alternatives is in the level of tail-pipe emissions. To remedy this, in USA, reformulated gasolines are being developed with lower sulphur content, better distillation characteristics, lower aromatic and olefin content, incorporation of MTBE, higher RON and MON. Reformulated diesel is also coming onto the scene with lower sulphur content and density, improved distillation characteristics and higher cetane number. Both types of reformulated products can help reduce emission levels, particularly the reduction of fuel sulphur content from 0.5-0.3% mass on diesel particulate emissions. But there will be a significant price to pay - estimated at an extra US$17-19 a tonne (Paramins Postal 1994)? There is also a problem regarding availability of supplies since it is currently insufficient for widespread use. In fact the USA already has to import components to meet its needs.

The PETRONAS refinery at Melaka has gone a step forward by being the first in the region to have a flexibility to cope with even the CARB (California Air Requirement Board) limits! The refinery has the flexibility to produce diesel with <10% aromatic and < 0.05% sulphur (Internal Report 1993).

ALTERNATIVE FUELS

To be successful, alternative fuels need to give low emissions and rival gasoline and diesel in terms of cost, supply, distribution, delivery to vehicles, on-board storage and power density. So the principal contenders for automotive use in USA are : LPG, CNG, methanol (M85), ethanol (E85) and hydrogen.

While the use of M85 is likely to increase, the supply of methanol itself is limited. It is low on energy content, there being a large energy loss in production; it suffers from water contamination; it attacks organic materials and metals; and needs more on-board storage capacity or vehicle range will be penalised. On the other hand, greater use will be made of methanol in the future in the synthesis C_3H_8 and C_4H_{10}, paraffins and the on-board production of hydrogen for fuel cells. Although environmentally attractive, the widespread use of hydrogen as an automotive use is not practical. Its production is low, there are no plans for distribution systems and on-board storage is difficult. Electricity and CNG in terms of energy are very cheap, but when the cost of the battery and high pressure on-board storage for electricity and CNG respectively are taken into account they become two of the more expensive fuels. *Table 2* shows the results of a study commissioned by the US Gas Research Institute. The study takes into account the full fuel cycle emissions and came up with a preliminary ranking of each fuel for its production of reactive organic gases eg. methane, CO, NOx, SOx, PM10 (particulate matter less than 10 microns) and CO_2. Whilst

TABLE 1. REGISTERED VEHICLES IN MALAYSIA UP TO 30 SEPTEMBER 1994 (CUMULATIVE)

TYPE	DIESEL VEHICLE		PETROL VEHICLE	
	Total	%	Total	%
LORRY	508,729	79.0	201,342	3.1
BUS	32,403	5.0	1,696	-
CAR	77,824	12.1	2,293,279	35.7
TAXI	24,945	3.9	23,239	0.4
MOTORCYCLE	-	-	3,905,492	60.8
TOTAL	643,901	100.0	6,425,048	100.0

TABLE 2. RANKING OF FUELS AS PER EMISSIONS

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US Gas Research Institute full cycle emissions study

	ROG	CO	NO_x	SO_x	PM_{10}	CO_2
Gasoline	8	7	2	5	4	4
Diesel	5	3	8	4	8	6
RFG	7	6	3	5	4	5
M85	5	4	4	2	3	8
E85	4	5	6	7	6	7
LPG	3	8	5	1	1	1
CNG	2	2	1	3	2	3
Electric	1	1	7	8	7	2

1 = BEST 8 = WORST

Source PARAMINS Post, Industry and Additive News (Sept 1994 - Issue 3/94)

TABLE 3. FUEL CHARACTERISTICS OF PALM OIL METHYL ESTERS (POME), MALAYSIAN DIESEL (MD) AND LOW CETANE DIESEL (LCD)

NO.	TEST		TEST METHOD	TEST RESULT		
				LCD	POME	MD
1	DENSITY @ 15°C	kg/l	D 1298	0.833	0.8764	0.8270
2	COLOUR (VISUAL)		D 1500	2.5	REDDISH	YELLOW
3	FLASH POINT PMcc	°C	D 93	67	188.0	76.0
4	SULPHUR CONTENT	%wt	IP 336	0.10	0.01	0.04
5	VISCOSITY @ 40°C	cST	D 445	2.353	4.75	3.33
6	CCR 10% RESIDUE		D 189	0.11	0.33	0.03
7	POUR POINT	°C	D 97	- 12	+15	+12
8	DISTILLATION		D 86			
	IBP	°C		168.0	309.0	185.0
	10% RECOVERY	°C		211.0	323.0	223.0
	20% RECOVERY	°C		226.0	325.0	244.0
	50% RECOVERY	°C		268.0	328.0	281.0
	90% RECOVERY	°C		347.0	341.0	368.0
	FBP	°C		371.0	349.0	403.0
	FINAL RECOVERY	ml.		98.0	99.5	98.0
	RESIDUE	% vol		1.0	0.5	1.5
	LOSS	% vol		1.0	-	0.5
9	CALCULATED C I		D 975	36	65.2	59
10	CALCULATED GCV	kj/kg		45,800	40,135	45,800
11	REACTION		JIS K2252	NEUTRAL	-	-
12	WATER DISTILLATION	% vol	D 95	L 0.05	-	-

rankings given are preliminary and minor changes are possible, the important finding is that no single alternative fuel is a clear winner in the emissions stakes.

BIOFUEL

Vegetable oil is another possible alternative but it cannot be used directly in direct injection (DI) diesel natural gas engines due to coking problems and degradation of the engine oil. There is considerable interest in vegetable derived fuels, in particular rapeseed methyl ester (RME) in Europe but not from the OEMS. Pressure for the use of RME comes from the farming lobby but there is no consensus that it makes economic or environmental sense (Paramins Post, June 1994). There are also concerns about elastomer compatibility, engine cleanliness and cold flow properties.

Generally speaking, there is a decreased smoke and particulates when vegetable oils are used as fuels for diesel engines. The thermal efficiency is also slightly better than when using diesel fuel, but low loads and revolutions during idling, the poor spray characteristics of vegetable oil fuels, due to their high viscosity, lead to carbon deposition and sticking of rings. When using vegetable oils in ordinary naturally aspirated diesel engine, it is necessary to lower the viscosity. This can be done by:

1) transesterification
2) blending
3) heating the fuel

However, it is possible to use vegetable oils in diesel engine where the engine design accommodates this, as in the case of the German Elco engines. However, it is essential to heat the oil to 60-70°C to ensure adequate flow. Because of the difference in viscosity, vegetable oils such as rapeseed and palm oils would not be able to give spray characteristics which are compatible with the commonly used injection equipment.

Most experiments conducted all over the world involve the use of methyl esters. Fatty acid esters do work well and give low smoke and emissions. In Europe, there are plans to use 220,000 tonnes of vegetable oil (mainly rapeseed) methyl esters (Murayama,1994). Italy (125,000 tons), France (50,000 tonnes) and Germany (5,000 tonnes) are the main European consumers of vegetable oils as fuel. In Italy, all will be used for air conditioning while in France, between 5-30% will be used as fuel in diesel engines. At present, ELF, TOTAL and other oil companies sell diesel fuel blended with 5% methyl esters and in some large cities, blends are used experimentally in buses and trucks. It is expected that the demand for biofuel in France will triple in 1995 compared to other countries due to the active intervention of the government as part of French agricultural policies (Murayama,1994).

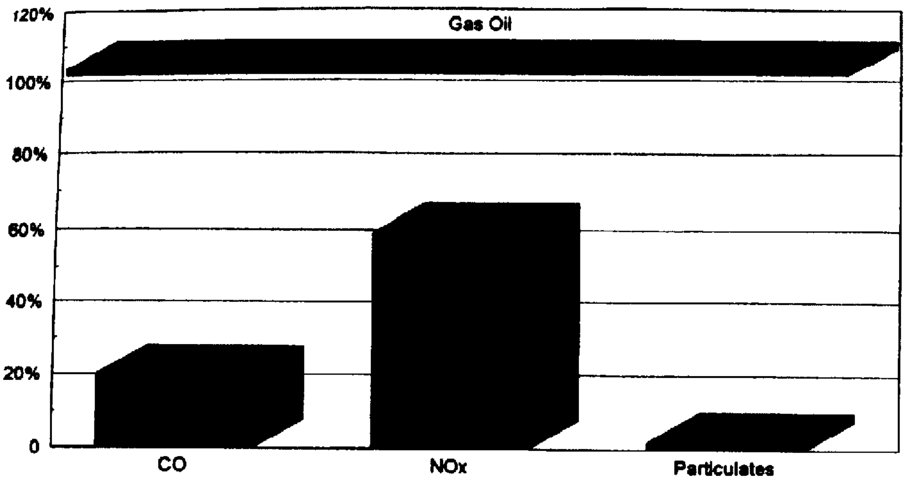
A comparison of exhaust emissions of diesel fuel and biodiesel is shown in *Figure 2*. The parameters which improve with biodiesel include smoke, polyaromatic hydrocarbons (PAH), unburnt hydrocarbons, SO_2, acetaldehyde and in many cases noise. There are reports of both increases and decreases in CO. Most report increases in NOx. Formaldehyde becomes a problem particularly at cold starting and during idling. The figure also shows an increase in benzene, probably due to formation from unsaturated compounds created during thermal decomposition. This is undesirable. In Italy, most biofuels are used for space heating or cooling and *Figure 3* shows emissions improvements, CO, NOx and particulate being lower than with diesel fuel.

CRUDE PALM OIL METHYL ESTER

In Malaysia, principal contenders for automotive use are LPG, CNG, crude palm oil or its methyl ester. Potential contenders could be our own crude palm oil methyl ester. While technically, palm oil methyl ester is a viable choice with improved emissions and at no substantial fuel consumption loss, using it as a neat fuel would be costly at the current price of crude palm oil. As a blending component, it could be an interesting alternative to consider. *Table 3* shows palm oil methyl ester fuel qualities. At Petronas R&D centre, we tested the use of palm oil methyl ester as both a neat fuel and as blend with petroleum diesel tested on both direct injection (DI) and indirect injection (IDI) research diesel engines. Palm oil methyl ester shows to be a promising substitute as alternative diesel fuel. From the study the following observations were derived.

Emission Levels

The results of the Hydra research engine study confirmed that palm oil methyl ester is a good alternative for diesel engine especially in IDI. The use of palm oil methyl ester in diesel engine lowers certain emission levels. The introduction of palm oil methyl ester into low cetane diesel seems to improve the smoke level. *Figures 4A* and *4B* show the smoke emissions on both DI and IDI engines test results. However, the improvement in emissions is not significant especially at low palm oil methyl ester dosage (at 10% and 20% v/v). This can be explained by the presence of the extra oxygen content in the molecular structure of the ester which lends it better combustion and smoke oxidation. Because of the increased oxygen



Source : INFORM, Vol. 5, no. 10(October 1994)

Figure 3. Emission from heating systems with vegetable oil and gas oil

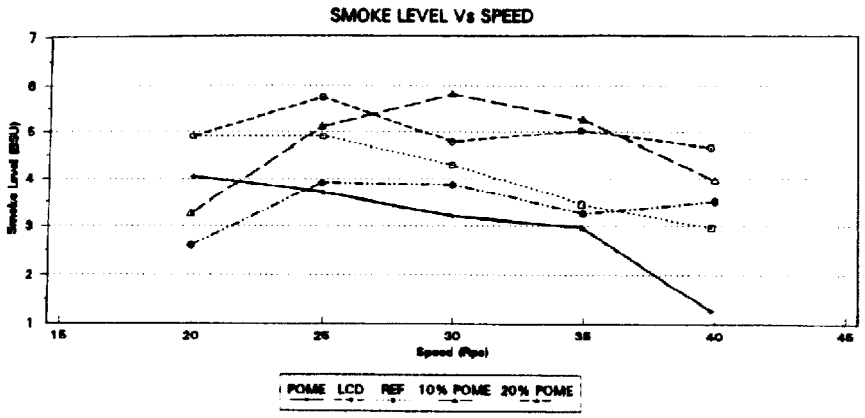


Figure 4a. Smoke level at various engine speeds (max. power, DI engine)

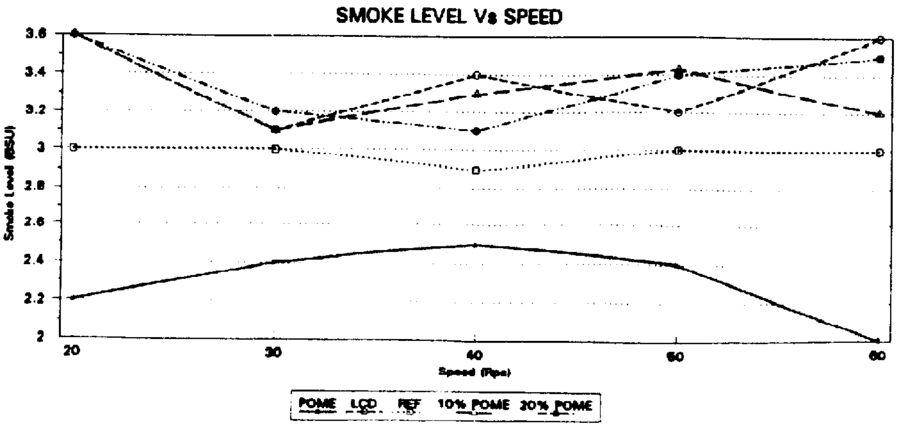


Figure 4b. Smoke level at various engine speeds (max. powe, IDI engine)

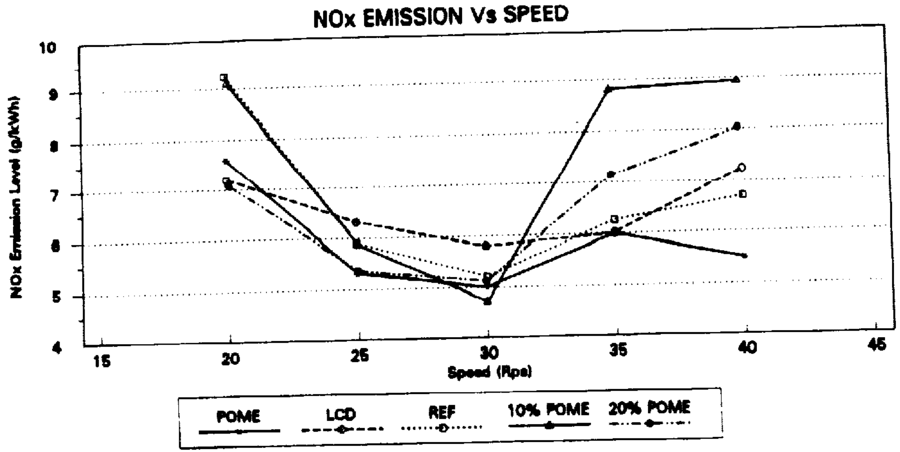


Figure 5a. NOx emission at various engine speeds (max. power DI engine)

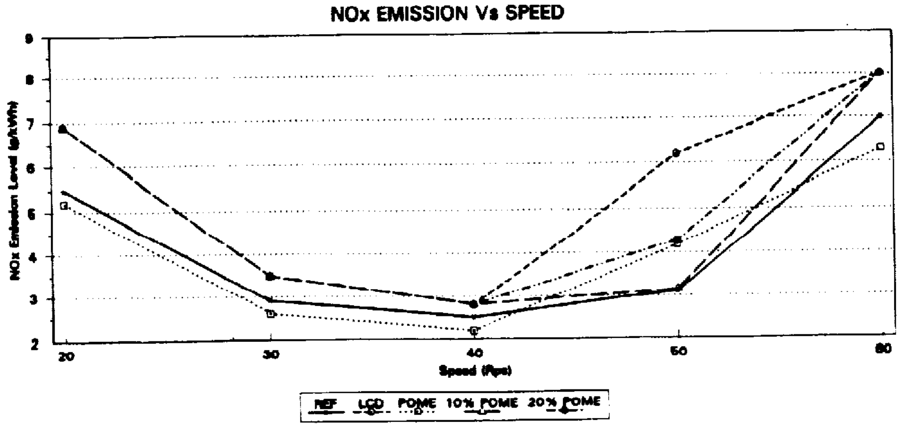


Figure 5b. NOx emission at various engine speeds (100% power, IDI engine)

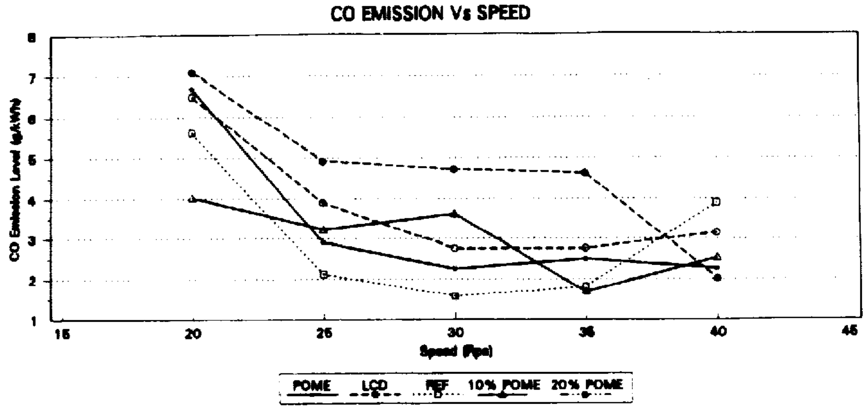


Figure 6a. CO emission at various engine speeds (max. power , DI engine)

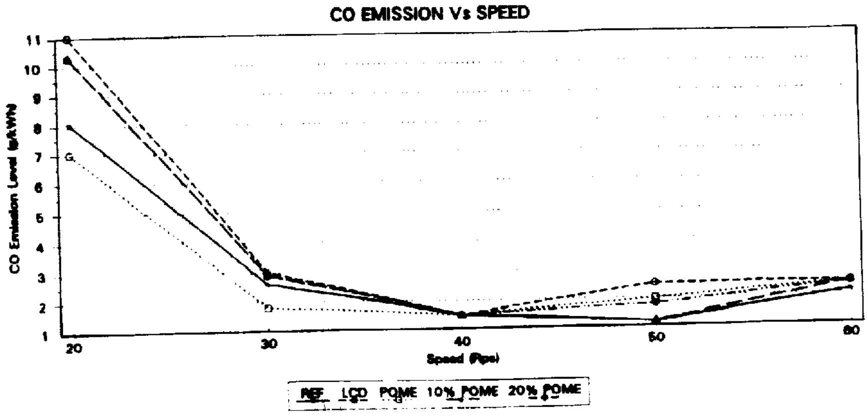


Figure 6b. CO emission at various engine speeds (100% power, IDI engine)

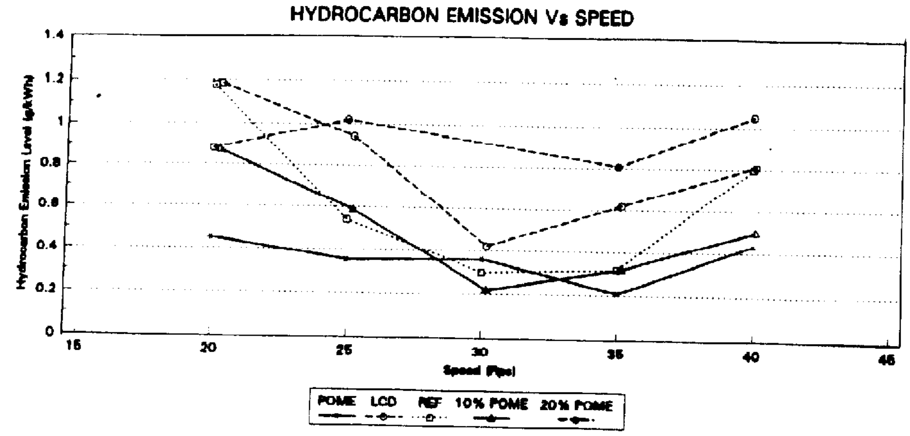


Figure 7a. Hydrocarbon emission at various engine speeds (max. power, DI engine).

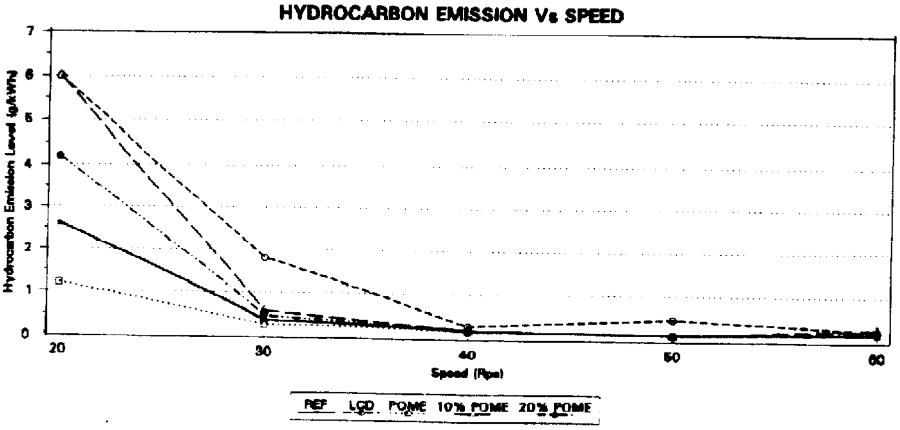


Figure 7b. Hydrocarbon emission at various engine speeds (max. power, IDI engine).

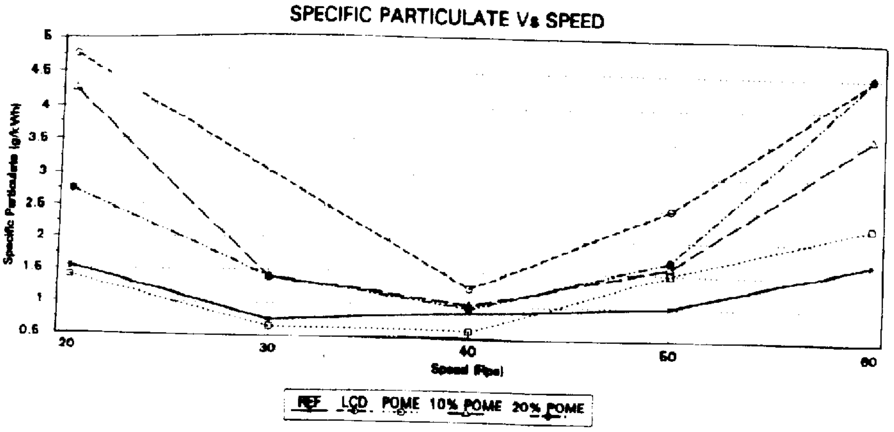


Figure 8. Specific particulate at various engine speeds (100% power, IDI engine).

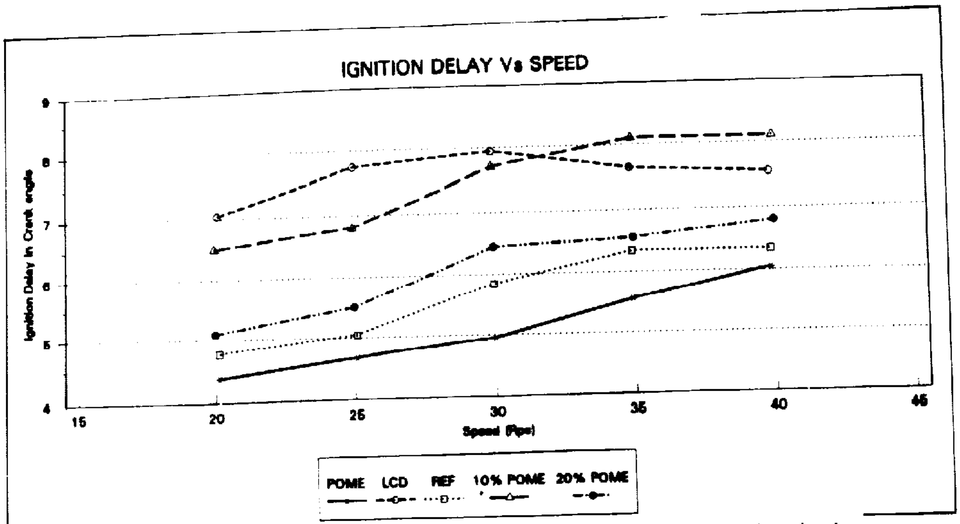


Figure 9a. Ignition delay at various engine speeds (max. power , DI engine).

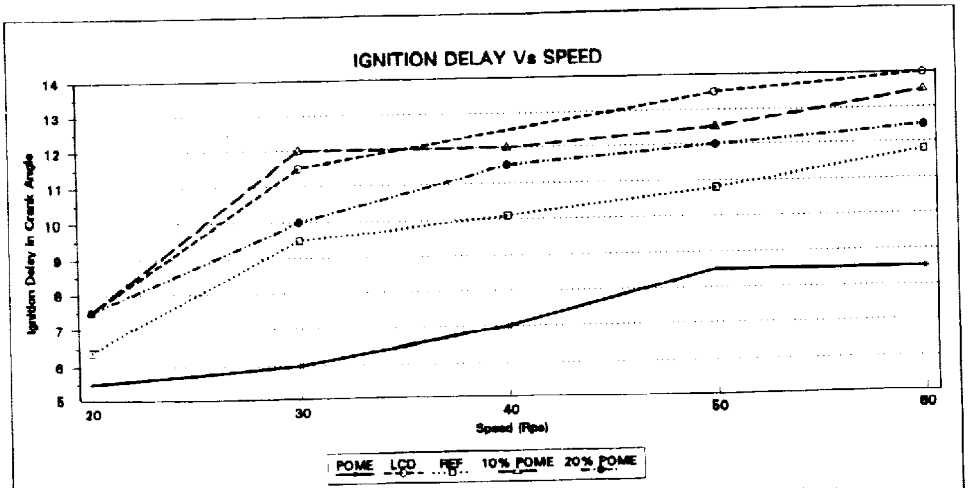


Figure 9b. Ignition delay at various engine speeds (max. power , IDI engine)

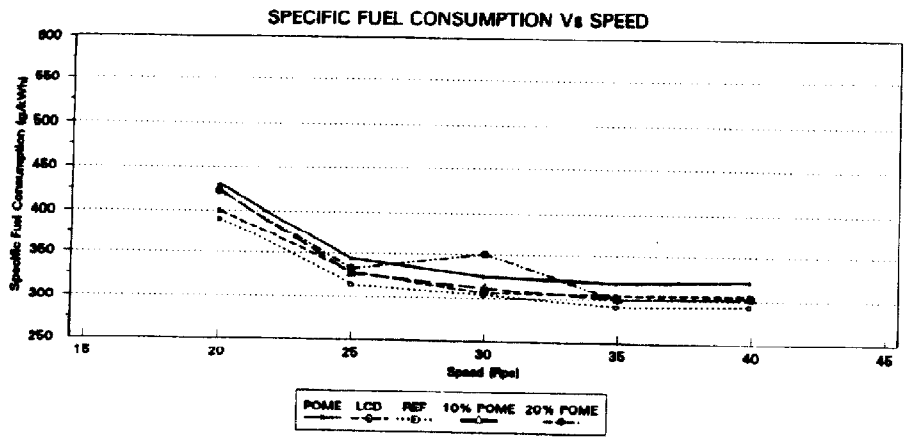


Figure 10a. Specific fuel consumption at various engine speeds (max. power, DI engine)

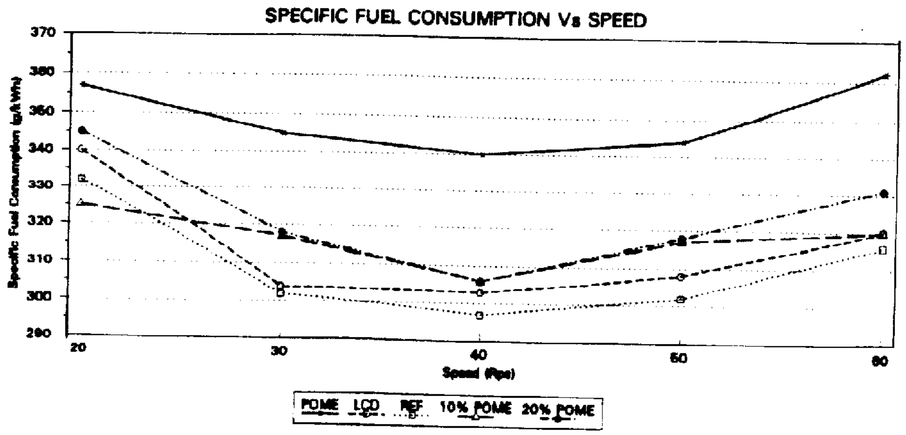


Figure 10b. Specific fuel consumption at various engine speeds (max. power, IDI engine)

availability of the ester fuel, the combustion temperature is higher, thus lower smoke emission. But the high temperature tends to increase the formation of NOx. *Figures 5A* and *5B* show the NOx levels mentioned above. This trade-off between NOx and smoke (particulate, refer *Figure 8*) is normal and it is difficult to drive both down.

Ignition Delay

Palm oil methyl ester has a lower ignition delay than diesel fuel. *Figure 9A* and *9B* show the ignition delays of palm oil methyl ester used on DI and IDI engines. The introduction of palm oil methyl ester actually improves the ignition delay of the low cetane diesel decreasing it substantially. The presence of palm oil methyl ester in the mixture improves the ignition characteristics of the mixture due to the presence of the extra oxygen in the molecular structure of palm oil methyl ester. The extra oxygen indirectly assists in better combustion of the fuel, hence lowering the ignition delay. The ignition delay however increases at a speed higher than 30 rps with the 10% v/v blend.

Specific Fuel Consumption

The specific fuel consumption on the other hand increases with the use of palm oil methyl ester due to the lower calorific value of palm oil methyl ester (refer to *Table 3*). *Figure 10A* and *10B* show the trend in fuel consumption increases with engine speed at both extremes.

CONCLUSION

Meeting widespread demand for reformulated gasoline and reformulated diesel will mean high levels of investment from oil companies and while this could help reduce emissions, greater reductions could be achieved by taking older vehicles out of service, regular maintenance and emissions checks, engine technology developments, more considerate driving, and better traffic management. Relative cost of the different fuels varies with location and locally imposed taxes. Where palm oil methyl ester is concerned, it is probably an answer to emissions reduction but it is the cost that will finally determine any swing to its favour. Using it as a blending component could be a feasible alternative.

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