PLANT OILS AS A FUEL FOR DIESEL ENGINES: EXPERIENCE WITH SUNFLOWER OIL.

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ABSTRACT

Since 1979, sunflower oil has attracted a lot of attention as a possible fuel for diesel engines. It has been shown that neat sunflower oil and blends of sunflower oil with petroleum fuels can power diesel engines. Coking of injector tips proved to be a problem. Ethyl- and methyl esters of sunflower oil proved to be very good fuels for diesel engines and prevented injector coking. Successful tests were conducted with indirect injection engines running on neat sunflower oil.

INTRODUCTION

Since 1979, countries like the Republic of South Africa, Australia and the United States of America became interested in the use of plant oils as possible fuels for diesel engines. In South Africa the researchers concentrated their efforts on sunflower oil (Bruwer *et al.*, 1980 and 1981) while in Australia and the USA, plant oils such as soya bean oil, peanut oil and cotton oil also received some attention (Galloway and Ward, 1979 and 1980; McCutchen, 1981; Kaufman *et al.*, 1981). In Europe, rapeseed oil was investigated.

The most important reason for the renewed interest in plant oils as possible diesel fuel replacements, was that farmers were getting nervous of not being able to get adequate diesel supplies during critical farming operations such as planting or harvesting. Plant oils had the immediate attraction of being able to power diesel engines while they can be produced on the farm. Farmers had visions of becoming completely independent from outside sources for their fuel supplies. Research on the extraction and preparation of sunflower oil on farms and the utilization of the fuel in agricultural tractors was begun.

On-farm sunflower oil extraction.

Screw-type presses with a range of capacities are listed in Table 1. The required capacity for a farm-type press is dependent on a number of factors; including, farm size (determining total fuel volume required per year), time available for oil extraction and storage volume available.

Table 1. Screw press capacities and prices: 1981.

Seed capacity, kg/h	Price, US $
200	22 400
300	33 600
500	47 600
1 500	207 400

A very small press (maximum capacity 40 kg/h) was tested to determine general behaviour patterns of screw presses. The machine was tested with a high and low oil content seed, at different speeds, with five different choke settings at each speed. The production rate of oil and cake, the cake thickness and cake oil content, power consumption and barrel temperatures were measured with each test. The oil contained in the "foots" was not taken into account in the figures for oil production rate. The seed was not decorticated.

On-farm sunflower oil ester preparation.

Ethyl ester and methyl ester of sunflower oil can fairly easily be prepared using quite unsophisticated equipment. A 2 000 litre steel tank normally used for storing diesel fuel on farms, was equipped with external piping, electrical heaters and a circulating pump. A manhole was cut in the top and a cooling tower installed to facilitate experiments at reflux temperature.

Ethyl ester could be prepared by using 0.5% catalyst (W:V) in conjunction with 33% ethyl alcohol to 67% sunflower oil. The sodium hydroxide catalyst was dissolved in the ethyl alcohol by circulating the alcohol through the catalyst for about an hour. The sunflower oil was then added and properly mixed with the alcohol and catalyst. A yield of more thn 90% ester was obtained at room temperature. The fuel was then treated with citric acid to precipitate the sodium hydroxide as sodium citrate. Distillation of the excess alcohol will reclaim some alcohol. After decanting glycerol, the product was washed with water and centrifuged.

Diesel engine tests with neat sunflower oil and ester.

Combustion properties of fuels were compared with those of diesel fuel in comparable engine operating conditions. A Perkins 4.236 engine was installed on a dynamometer test bed and instrumented with a cylinder pressure transducer, a crank angle indicator and thermocouples to monitor temperatures for inlet manifold air, ambient wet- and dry bulb, fuel, lubricating oil, coolant and exhaust gases. As oscilloscope was used to display curves of the cylinder pressure and injector needle lift against crank angle.

Power take-off tests were conducted on five makes of agricultural tractors, nine models in all. Maximum power, fuel consumption and smoke values were measured comparing performance on diesel and sunflower oil. Long-term effects of sunflower oil on diesel engines were also studied.

Two identical indirect injection engines were installed in agricultural tractors and tested on degummed, filtered sunflower oil. The tractors were coupled to pto dynamometers which could be controlled by computer to put varying loads on the tractors. One engine was subjected to the manufacturer's cyclic load and the other one was run continuously on a load of 70% of maximum power.

RESULTS

Results of some of the tests on the small screw press are shown in Figures 1 and 2.

Figure 1. Maximum feeding rate of sunflower seed with 40.5% oil content, at different choke settings and speeds.

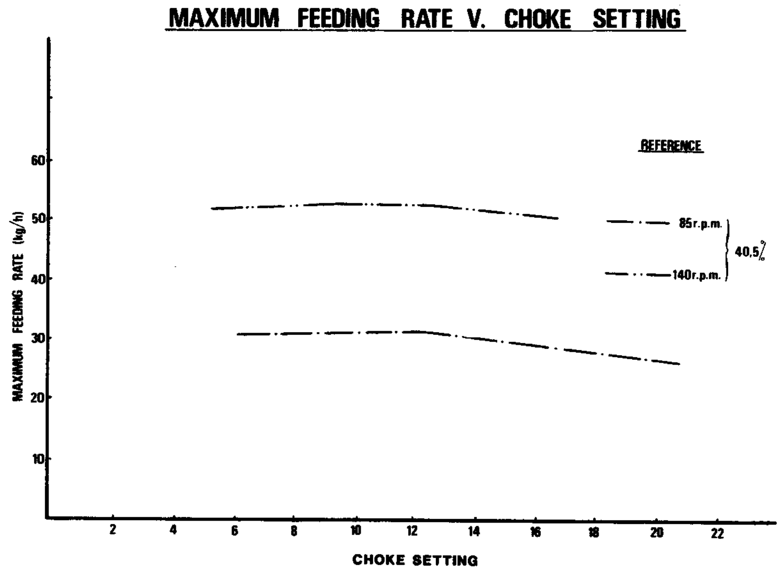

Figure 2. Oil discharge rate vs choke setting, for sunflower seed with different oil contents.

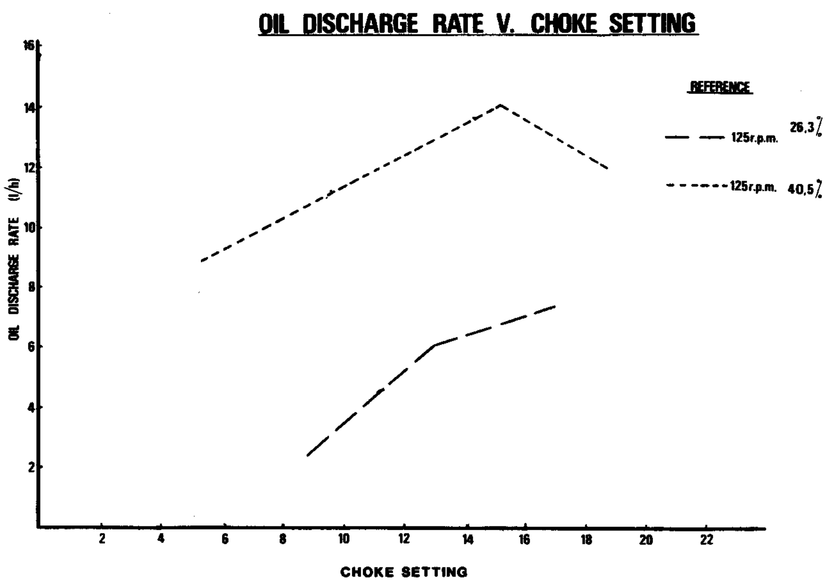

Table 2 shows results of tractor engine performance on neat sunflower oil. Tractors operating on neat sunflower oil for as little as five hours showed signs of injectors coking up, Continued operation resulted in piston rings sticking and lubricating oil polymerization. The use of sunflower oil ester could prevent injectors from coking up. Long-term tests with ethyl ester are still being conducted. Results of combustion studies with ethyl esters and methyl ester are shown in Table 3.

Table 2. Performance of various tractor makes with distillate and sunflower oil as fuels (after Bruwer *et al.*, 1981).

Tractor	Maximum Power (kW)		Maximum Torque (Nm)		Specific Fuel Consumption at P max (Mℓ/kWh)		Brake Thermal Efficiency at P max (%)		Smoke Value (Hartridge Units)	
	Distillate	Sunflower oil	Distillate	Sunflower oil	Distillate	Sunflower oil	Distillate	Sunflower oil	Distillate	Sunflower oil
MF 240	27.8	28.2	139	137	324	347	30.7	30.6	39	43
MF 285	41.6	40.0	214	198	334	365	29.8	29.1	56	51
Landini 8500 2WD	51.3	49.3	240	229	332	363	30.0	29.3	63	71
Landini 8500 4 WD	47.8	46.2	239	229	317	348	31.4	30.5	57	54
Fiat 780 4 WD	43.4	41.7	183	161	348	376	28.6	28.2	62	79
Fiat 880	61.0	59.8	271	249	324	345	30.8	30.7	60	42
John Deere 2030	41.5	40.2	183	171	355	395	28.0	26.9	67	70
I H 844-S	54.6	51.1	259	258	330	348	30.1	30.5	64	57
I H 1066 (Turbo-charged)	81.3	79.2	418	386	350	340	28.4	30.2	34	20

Altitude: 1 300m
Ambient Temp. 0 — 35°C
Daytime Ave. Temp.: 18 — 25°C

Table 3. Measured parameters in comparative analysis of sunflower oil esters and diesel fuel in a Perkins 4.236 diesel engine (Hawkins *et al.*, 1981).

Fuel	Lower Heat Value MJ/kg	Test Condition	Power kW	Fuel Consumption ℓ/h	Specific Fuel Consump. mℓ/kWh	Brake Thermal Eff. %	Hartridge Smoke Value	Dynamic Timing °BTDC	Ignition Delay °CA
Ethyl Ester 1	37	*Pmax	47.0	15.02	319.6	35.1	20	17.5	13
Diesel	42.7	Pmax	49.0	15.02	306.3	32.4	62	17.4	13
Ethyl Ester 1	37	**Tmax	34.0	10.87	319.5	35.1	44	17	11
Diesel	42.7	Tmax	35.4	10.9	308.2	32.2	84	17	10
Methyl Ester 1	35.3	Pmax	44.9	14.77	329.0	35.4	31	20	13
Diesel	42.7	Pmax	46.2	14.49	313.9	31.6	63	20	12.5
Methyl Ester 1	35.3	Tmax	32.4	10.80	333.9	34.9	65	20	12
Diesel	42.7	Tmax	33.7	10.79	320.0	31.0	85	20	11.5
Ethyl Ester 2	34.5	Tmax	34.1	11.69	343.0	34.7	—	19.5	14.2
Diesel	42.7	Tmax	35.2	11.61	330.1	29.8	—	19.5	13
Ethyl Ester 2	34.5	Pmax	43.2	15.13	350.2	34.0	—		
Diesel	42.7	Pmax	44.4	14.70	333.2	29.7			

* Maximum power, full throttle ** Maximum torque

The indirect injection engines did not seem to be adversely affected by the use of sunflower oil as fuel. One engine completed the manufacturer's factory cyclic load test of 600 hours duration. Having dismantled and inspected the engine, the factory expert declared that no adverse effects could be detected. The second engine had completed 2 300 hours on a constant load of 70% maximum power. At 1 000 hours the exhaust valve on one cylinder had burned while another exhaust valve on another cylinder burned at the 2 000 hour mark. It is yet unknown whether this could have been caused by the sunflower oil.

DISCUSSION

Direct injection engines run very well on neat sunflower oil, without the need to adjust them in any way. The fact that this type of engine will develop coked injector tips, which will ruin the engine in the long run, leads to the conclusion that the oil should be chemically changed to a form which is more acceptable to the engine. Ethyl or methyl ester of sunflower oil holds the promise to the solution, but much research still needs to be done in this field.

The promising results obtained with the indirect injection engines, seem to point to the fact that this type of engine may run quite happily on sunflower oil. Other makes of indirect injection engines are now being tested.

From all these tests, it may be concluded that plant oils show a lot of promise as replacements for diesel fuel, but a lot of research still needs to be done to solve problems encountered when engines are run for extended periods of time on plant oils.

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ENERGY FARMING UPDATE — THE BIO-OIL OPTION.

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ABSTRACT

Renewable fuels from crops are one class of alternatives for our diminishing fossil fuel reserves. Liquid fuels from crops are discussed, with particular emphasis on the potential for vegetable oils as replacements/extenders for diesel fuel.

An overview of the situation and the problems with using vegetable oils as fuels for diesel engines are discussed. The primary constraint is still cost and the second is the lack of warranty from engine manufacturers if these non-conventional fuel alternatives are used.

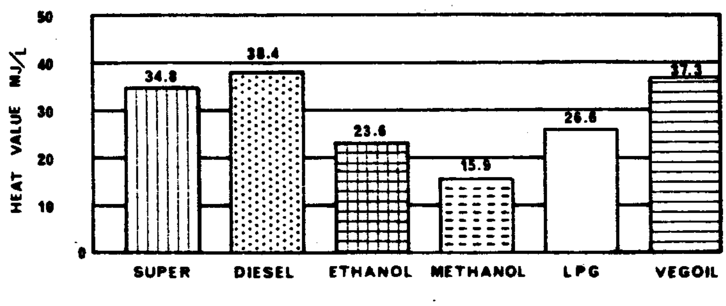
INTRODUCTION

Australian broadacre agriculture is dependent on the diesel engine. Changes in the fuel situation — changes in price, availability or quality of diesel distillate — directly affect the rural economy. Farmers have experienced traumas in all three of these areas and some regard renewable fuel alternatives such as ethanol or bio-oils as the answer to their energy problems, even to the extent of considering producing their own fuel, although they would not contemplate processing their own mutton, molasses or marmite.

A 'state of the art' seminar on Vegetable Oils as Diesel Fuels was held in Peoria, Illinois, Oct. 1981. At this USDA-sponsored seminar many new programs on the subject were reviewed and unpublished results were summarised, including work being undertaken by certain engine manufacturers. Pertinent findings from the seminar are reported in this paper.

Those features which make alcohol fuels attractive for use in spark-ignition engines — high octane rating particularly — militate against their sole use in unmodified compression ignition engines. Aside from this, the energy density of fuel alcohols is from one half to two-thirds that of the same volume of diesel fuel, Figure 1.

Figure 1. Fuel energy density spectrum of selected fuel on volumetric basis. Figures quoted are higher calorific values.



Bio-oils, on the other hand, have energy densities over 90 percent of that of diesel fuel. The term Bio-oils is coined for oils of recent biological origin, as distinct from fossil-derived hydrocarbons. Bio-oil fuels thus could come from plant foliage or latex-derivatives, or from the oilseeds which are of primary concern at this meeting, as well as from animal fats and algal sources. Of all these, oilseed crops are the nearest to being a substitute or extender for diesel fuel, in terms of potential for expansion in production agriculture, ease of extraction and cost. Palm oil and the Chinese tallow tree have been identified overseas as the most productive in terms of energy yield per unit land area — oil yields as much as five times that of sunflower are considered possible (e.g. 188 GJ/ha for palm oil vs say 38 GJ/ha for sunflower oil) — but these crops are not a component of Australian agriculture. In an emergency, sunflower, soybean, cottonseed, safflower, rapeseed, linseed and peanut oils would be the prime candidates as diesel engine fuels, roughly in that order of crop availability.

A comparison of the pertinent fuel-related properties of sunflower oil is shown in the table.