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✿ Canola and High Erucic Rapeseed Oil as Substitutes for Diesel Fuel: Preliminary Tests

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ABSTRACT

A cooperative project using the facilities of the POS Pilot Plant Corporation, the Saskatchewan Research Council and the Agricultural Engineering Department, University of Saskatchewan, and funded by Agriculture Canada, was initiated in 1980 to investigate the feasibility of using canola and high erucic rapeseed oil as a replacement/extender to diesel fuel in direct-injection diesel engines. Work carried out included the documented production and refining of canola and R500 (high erucic) vegetable oils, preparation of methyl ester and of blends of all these fuels with methanol and ethanol. These fuels were evaluated by ASTM and improvised tests to determine their usefulness as diesel fuel. Engine tests involved a 2-cylinder Petter diesel and a 6-cylinder John Deere turbocharged diesel. Results were similar for both engines in short-term performance tests, and indicated that: (a) maximal power was essentially the same when burning canola oil as when burning diesel fuel; (b) specific fuel consumption was ca. 6% higher when burning canola oil, but because canola oil has a heating value 14% less than diesel fuel, the thermal efficiency is somewhat higher when operating on canola oil; (c) there were no starting problems down to 10 C; (d) there were fewer particulates in the exhaust when burning canola oil; and (e) there was generally less combustion noise when burning canola oil. The high viscosity of canola oil (ca. 35 times that of diesel fuel at 20 C) poses a major problem in using the oil at low temperature. Blending with diesel fuel and the creation of a methyl ester from the canola oil both proved effective in reducing viscosity, but neither lowered the pour point appreciably. Efforts on reduction of pour points and further work on blends and on heating the fuel are described.

INTRODUCTION

With regard to the potential use of vegetable oils as alternative fuels for diesel engines, there are at least three questions that need to be resolved. The questions include: (a) Is there a favorable energy balance? (b) Is land available to produce the oils? (c) What is the technical feasibility of using the oils?

From a variety of calculations based on studies in different countries, we have estimated that the ratio of output energy to input energy for producing canola oil is in the range of 3:1 to 5:1 (1-3). This compares very favorably with the production of ethanol from biomass fermentation, there ratios between 1:1 and 1.6:1 are commonly quoted (4).

In an attempt to determine the feasibility of a farmer growing sufficient canola to supply his own fuel, we calculated that a farmer farming 400 ha would need 670 GJ or 16,940 kg canola oil (5). At yields of 1000 and 1500 kg/ha (6), assuming an oil content of 40% and 70% extraction efficiency, a farmer farming the average farm of 400 ha would have to use 10-15% of his land area to produce sufficient fuel for his needs.

Thus, in terms of energy return and land usage, canola oil is a practical replacement for diesel fuel and it is reasonable to proceed to determine solutions to technical problems which may arise in using it as a diesel fuel.

Early in 1980, a cooperative project utilizing the facilities of the POS Pilot Plant Corporation, the Saskatchewan Research Council and the Agricultural Engineering Department, University of Saskatchewan, and funded by Agriculture Canada, was initiated to achieve the following objectives:

- To determine the technical feasibility of using rapeseed oil as a diesel fuel extender or substitute. Both canola varieties and a high erucic variety to be included.
- To compare oils at various stages of refinement with diesel fuel.
- To conduct engine tests on different oils.
- To investigate the use of diesel fuel/vegetable oil/alcohol blends in engine tests.
- To undertake preliminary tests on a small expeller.
- To study exhaust emissions while running engines on

DISCUSSION

Oil Recovery

Even with the cage change and various changes in spacing between the plates of the cage for the mini-40 screwpress, we could not keep the machine operating for extended periods. We switched our feeding method from controlled flow to flooded inlet and we had no further problems with long-term operation. We have even operated the machine continuously for several days with dehulled canola and obtained good oil removal.

Residual oil in the meal has been as low as 12%. Most of our work has been carried out to achieve residual oil in the 16-20% region (canola seed has ca. 42% oil). At these rates we obtained throughput of ca. 25 kg/hr for dry seed of less than 7% moisture.

This rate dropped to 15 kg/hr at a seed moisture of 10%. To achieve equivalent oil removal at higher moisture it was necessary to close the choke down and thus reduce the throughput.

Oil Properties

The low cetane number obtained for canola oil implies that canola is a poor fuel for diesel engines. Similarly, the distillation curves (Fig. 3) can be interpreted to show that canola could cause abnormal combustion. Actual engine tests do not bear out these contentions, so it appears that many of these tests are not applicable to canola. Diesel fuel is oxidatively more stable than canola, and the ASTM distillation test measures a true distillation for this fuel, whereas, for canola oil, the test is measuring an oxidative destruction of the fuel followed by a distillation of the oxidative fragments.

Figure 4 shows the relationship of viscosity to temperature for canola, diesel, various mixtures of the two and also methyl esters of canola. Like all vegetable oils, canola is much more viscous than diesel and the viscosity is much more temperature-dependent. This high viscosity makes the oil much more difficult to pump at low temperatures and modifies the spray pattern from the jet in the engine. The viscosity problem was corroborated by a simple test involving flow rate through a 5-micron filter at decreasing temperature (Fig. 5). Canola flow at the same pressure is always

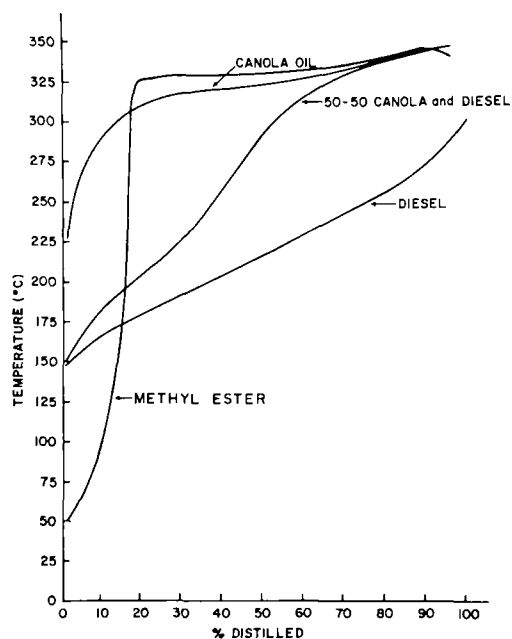


FIG. 3. ASTM distillation curves.

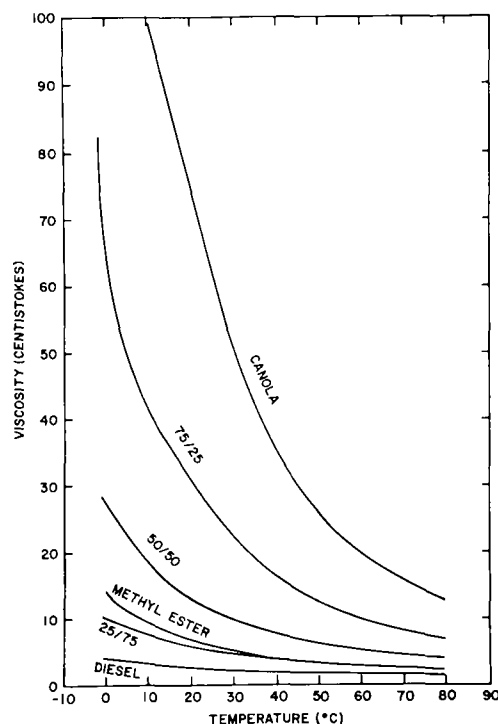


FIG. 4. Viscosity vs temperature for canola and diesel blends.

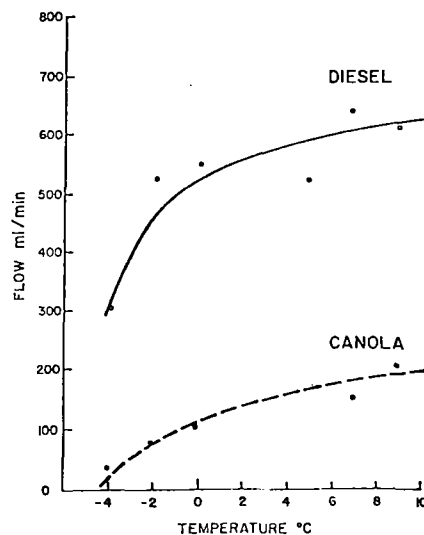


FIG. 5. Comparison of flowability of diesel and canola oil at low temperatures. Pressure 55 kPa measured ahead of first filter.

lower than diesel and drops essentially to 0 at -4 C.

Viscosity of the oil or diesel can be reduced substantially by adding alcohol to the fuel or by forming methyl esters (Table II). It was determined that up to 13% (by volume) anhydrous alcohol can be blended with canola and remain miscible. The blends, however, are unstable as the alcohol evaporates and the viscosity returns to that of the original fuel.

Methyl esters appear to be an attractive alternative. Unfortunately, they have a high pour point. Table III shows an evaluation of flowability of seven different fuels or blends which were subjected to a range of low temperatures. It can be concluded that blending canola with diesel, conversion to methyl ester or blending with alcohol has little effect on pour point flowability.

TABLE II

Viscosities of Diesel and Alternative Fuels @ 37 C

Fuel	Viscosity centistoke
Diesel	2.96
Diesel + 10% ethanol	2.41
Canola oil	37.82
Canola oil + 10% ethanol	21.15
Methyl esters	6.94
Methyl ester + 10% ethanol	5.08

Small Engine Tests

All data recorded here were from straight canola oil. The following were either monitored or evaluated by observation.

Maximum power (Fig. 6). These curves were obtained by operating the engine at governed speed and increasing the dynamometer load until maximum power was obtained. It can be observed that the canola oil produced slightly more power – 8.7 kW compared to 8.25 kW with diesel fuel.

Fuel consumption (Fig. 7). Minimum specific fuel consumption for canola oil was higher – a maximum of 6%. Given the fact that the canola oil has a heating value ca. 14% less than diesel fuel, the engine is apparently operating at a higher thermal efficiency on canola oil.

Smoke level. With a Clayton Opacity Meter, the reading when operating on diesel fuel was 17.0%, compared to only 12.1% for canola oil. This confirmed the impression of most observers, that there was considerably less smoke when burning canola oil.

Smoothness of operation. This could not be evaluated by measurement, but all observers agreed that there was less combustion noise when operating on canola oil in spite of its lower cetane number.

Starting. No problems were encountered in starting the engine on canola oil, down to 10 C, the lowest temperature encountered.

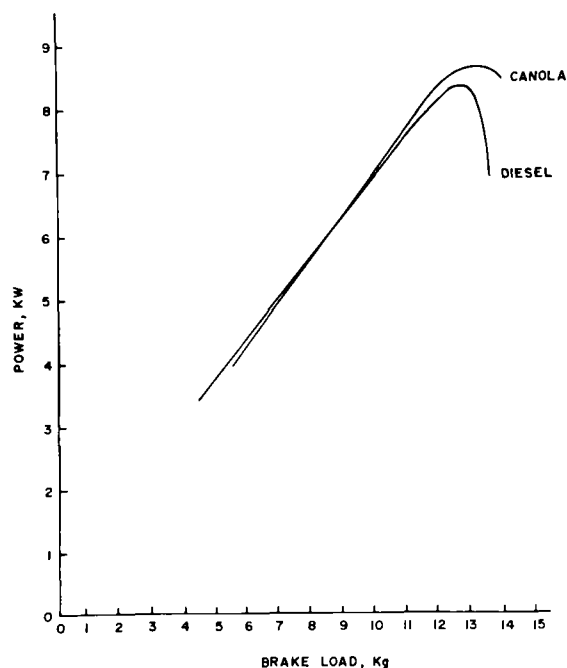


FIG. 6. Power curves: canola oil vs diesel.

Tests with alcohol blends. A series of short tests were run to assess the use of methyl ester, and alcohol blends with various fuels. These tests were run at the maximum torque load (Table IV). The power obtained with methyl ester was marginally lower than with either canola oil or diesel fuel, and the fuel consumption was measurably higher. It can also be seen that the addition of ethanol reduced power and increased fuel consumption for all fuels. The addition of 10% ethanol to any of the fuels increased the combustion noise considerably.

Large Engine Tests

Maximum power. This was ca. 2% less when running on canola oil – 168 kW vs 172 kW on diesel.

TABLE III

Fluidity for Various Fuels

Temp (C)	90% Canola/ 10% diesel	75% Canola/ 25% diesel	50% Canola/ 50% diesel	100% Canola	90%Canola/ 10% ethanol	Methyl ester	90% Methyl ester/ 10% ethanol
- 6	Fluid	Fluid	Fluid	Fluid	Fluid	Fluid	Fluid
- 9	Fluid	Fluid	Fluid	Fluid	Fluid	Cloudy fluid	Fluid
- 12	Fluid	Fluid	Fluid	Cloudy Fluid	Fluid	Very cloudy	Fluid
- 15	Fluid	Fluid	Fluid	20% Solid	10% Solid	Very cloudy	Fluid
- 18	50% Solid	Fluid	Fluid	50% Solid	30% Solid	Solid	Cloudy
- 21	70% Solid	40% Solid	20% Solid	70% Solid	50% Solid	Solid	Very cloudy
- 24	90% Solid	60% Solid	40% Solid	90% Solid	Solid	Solid	Very cloudy

RAPESEED OILS AS DIESEL SUBSTITUTES

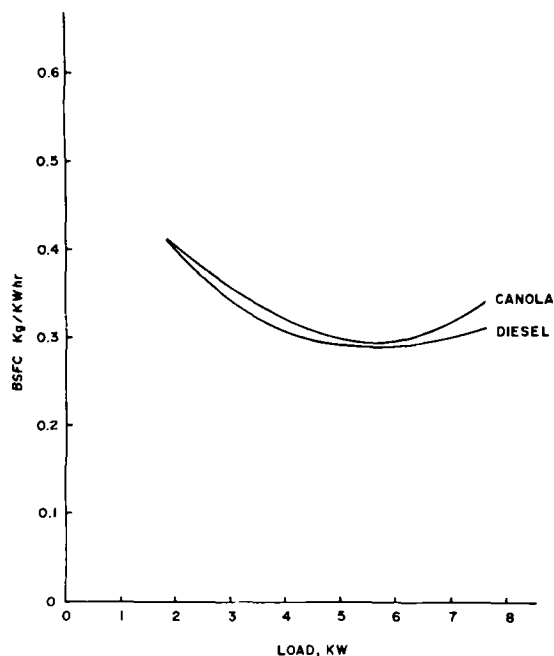


FIG. 7. Specific fuel consumption: canola vs diesel.

TABLE IV

Power and Specific Fuel Consumption for Various Fuels Tested

Fuel used	Power maximum torque (kW)	Minimum specific fuel consumption (kg/kW-hr)
Diesel	8.10	.336
Diesel + 10% ethanol	7.85	.345
Canola	8.11	.339
Canola + 10% ethanol	7.90	.359
Methyl ester	8.01	.366
Methyl ester + 10% ethanol	7.84	.376

Fuel consumption. Specific fuel consumption was ca. 6% higher when running on canola, again indicating improved thermal efficiency for the canola oil.

Smoothness of operation. there was no noticeable difference between the two fuels.

Starting. No problems were encountered down to 10 C.

Effect of refining. A comparison was made of five different oil samples as follows: (1) degummed, expeller Regent oil; (2) degummed, refined, expeller, Regent oil, (3) degummed,

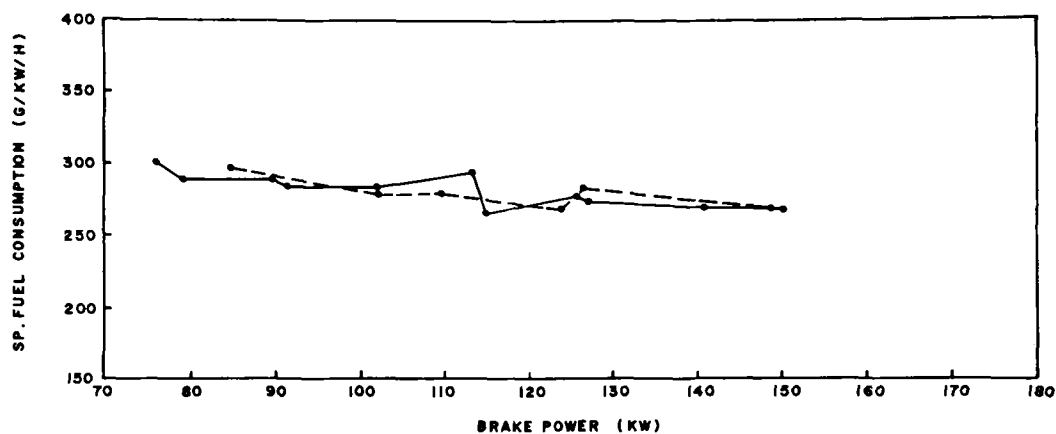


FIG. 8. Specific fuel consumption for canola. Duplicate runs with degummed, refined Regent extractor oil.

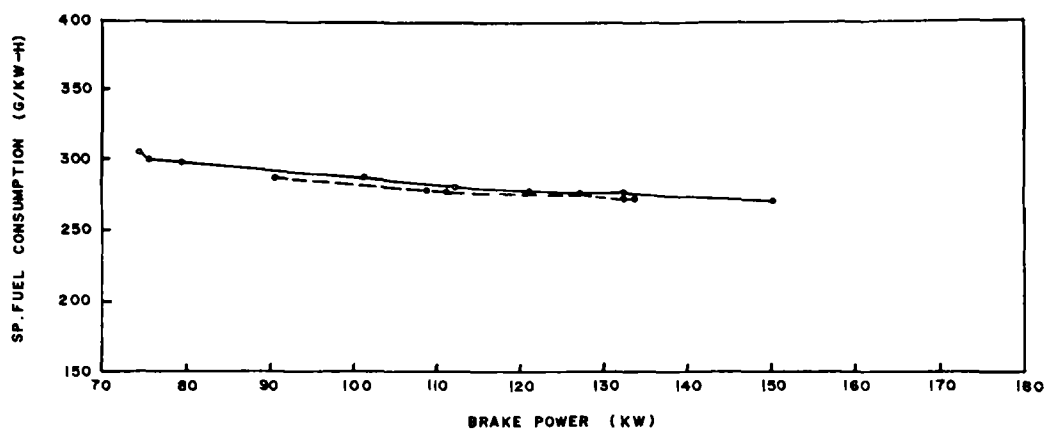


FIG. 9. Specific fuel consumption for rapeseed. Duplicate runs with degummed refined R500 oil.

refined, extractor Regent oil; (4) degummed, R500 (high erucic), expeller oil; and (5) degummed, refined R500 (high erucic), expeller oil. Stage of refinement of type of canola oil has little significant effect on maximum power or fuel consumption. Figure 8 shows duplicate runs with the #3 fuel, and Figure 9 with #5 fuel tends to verify this conclusion. All other fuels were similar.

Emission Studies

In the work done to date, only a preliminary study has been made of exhaust emissions on the Petter engine. In general, the particulate level when burning canola oil was 20-60% of the level when burning diesel fuel, depending on engine load. This result is in agreement with the smoke opacity readings taken on the Petter engine. It was also found that the aldehyde and NO_x levels were significantly lower with canola oil – for example, aldehydes for canola oil were ca. 60% of the levels for diesel fuel.

Future Studies

The results to date have been sufficiently encouraging to warrant further investigation, including: a study of engine deposits with various fuels; a study of lubricating oil contamination; a detailed analysis of exhaust emissions; continual work with small extractors; further investigation of

various esters of canola oil; further investigation of the low temperature problems, and possible solutions; and endurance tests.

ACKNOWLEDGMENTS

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✂ Effects of Processing and Chemical Characteristics of Plant Oils on Performance of an Indirect-Injection Diesel Engine

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ABSTRACT

Engine performance curves were obtained for crude, degummed, and degummed-dewaxed sunflower oils and for crude, degummed, and alkali refined cottonseed oils using a single-cylinder, precombustion chamber design diesel engine. Crude oils gave very poor performance and are considered unsuitable for use as alternative diesel fuels. Performance curves for processed sunflower and cottonseed oils were slightly better than for diesel fuel, but increased carbon deposits and lubricating oil fouling were noted. Although processed oils may be acceptable fuels for short-term use, they are not recommended as alternative diesel fuels at this time.

INTRODUCTION

Farmers are looking to alternative fuels for security during emergency petroleum shortages, as a new outlet for farm products and also as a way to achieve greater independence. The most appealing alternative fuels are those which can be used with minimal modification of existing engines. For the farm sector, which has become heavily reliant on diesel power, much attention has been focused on plant oils as direct substitutes for diesel fuel.

Although there are many reports that diesel engines will operate on plant oils, either alone or blended with diesel fuel, there is no clear definition of characteristics a plant oil should have to be a good substitute diesel fuel. In addition, long-term effects of alternative fuels on factors such as maintenance and engine wear have only recently been reported.

Reports comparing different types of plant oils in a

given engine show wide differences in performance characteristics (1-4). These differences likely are related to chemical or physical properties of the oils such as viscosity, fatty acid composition, degree of unsaturation, molecular weight and contents of minor compounds. However, those studies have not included characterization of test fuels to allow a determination of why the fuels gave different engine performance results.

Performance results reported for a given type of oil also show considerable variation, particularly for cottonseed oil. Satisfactory results with cottonseed oil have been reported (5, 6). However, unsatisfactory results reported for cottonseed oil include excessive carbon formation at the injector nozzle tip (7), corrosion of engine parts (1), and complete inability to run engines (8, 9). Despite the corrosion resulting from use of cottonseed oil, Chowhury (1) reported that cottonseed oil gave the highest thermal efficiency of all fuels tested, including diesel fuel. Although Ryan et al. (9) reported lack of ignition using 100% cottonseed oil, satisfactory performance was reported using a 90% cottonseed/10% diesel blend. These conflicting results with cottonseed oil may have been caused by differences in test engine designs, processing of oils used, or environmental factors (e.g., temperature).

In this paper, performance characteristics of a single-cylinder diesel engine using various sunflower oil (SFO) and cottonseed oil (CSO) fuels are reported. These data allow comparison of effects on engine performance of different types of oils and also of processing an oil through various stages of refining.