Winter Rape as an Alternative Source of Fuel

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At the University of Idaho, research is being directed at using rapeseed as a fuel -- oil as a diesel fuel substitute and the meal and plant biomass as a woodstove or boiler feedstock. Use of vegetable oil as a fuel has been underway since 1979 when a blend of sunflower and diesel was used to power an agricultural tractor. Since that time most of the work has concentrated on winter rape oil as a replacement for diesel fuel. This highly saturated oil has consistently, in our tests, been superior to other vegetable oils as a possible engine fuel.

Research related to use of the meal as a potential fuel for direct combustion has been in progress for less than one year. The high glucosinolate level in the meal of Dwarf Essex variety; the common variety grown in the Pacific Northwest, makes it undesirable for use as a livestock feed but it's high energy content makes it a potential source of biomass for direct combustion.

The use of the meal and plant biomass in direct combustion raises the possibility of growing winter rape as a total energy crop, with no need for the crop to compete in either the food or feed grain markets. This use would increase the possibility of petitioning for the right to grow winter rape for energy on CRP or set aside agricultural land totally for on-farm or rural energy purposes. This paper will give a brief report of progress in each of these areas of research.

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Extracting and Processing Vegetable Oil

Three methods of removing oil from the oil seeds are currently in use:

1. A simple mechanical screwpress, which is considered most suitable for on-farm use.

2. The solvent extraction process, in which the crushed oil seeds are soaked in a solvent such as hexane, the meal is removed, and the hexane evaporated leaving the oil. The complexity and hazards associated with solvent extraction are generally considered undesirable for small on-farm processing plants. However, hexane extraction is a likely method for larger plants.

3. Solvent extraction combined with a light screwpress is the most likely approach for larger plants and is the general method used by most commercial oilseed expression plants.

At the University of Idaho, a small mechanical screwpress of 40 kg/h capacity is used to extract oil from rapeseed. To date, 4500 gallons of oil have been processed. The press has had an average extraction efficiency of 80-85 percent. The press should reduce the oil content from 42 to 45 percent in whole seed to 14 or 15 percent in the processed meal. For this reason, small screwpresses are less satisfactory for the oil seeds such as soybeans, which have oil percentages of 18 to 20 percent, than for peanuts rapeseed and safflower, which have oil percentages of 40 to 50 percent.

Power requirements are approximately 1 horsepower per ton of daily capacity. Seed is generally preheated to a temperature of 50 to 100 degrees C for 15 to 20 minutes. Research shows that temperatures at the low end of the range are adequate for rape.

Filtering the oil is necessary and involves (1) allowing the oil to settle for a minimum of 48 hours and then (2) filtering through a series of elements ending with a 4 to 5 micron filter.

Most vegetable oils contain small amounts of phosphatides called "gums" and free fatty acids that are removed by hydrating with steam or hot water. After hydration, the water will settle to the bottom, and the oil is siphoned off. A simple filtration system can be easily constructed from readily available components. One such system used a roller pump of the type used on farm sprayers to pump the oil through a series of throw away filters and a final fuel filter from a diesel engine.

Most researchers have reported fuel filter plugging to be a problem when using vegetable oil, and appropriate precautions should be considered. The addition of a dispersant type diesel fuel additive reduced filter plugging four-fold.

Vegetable Oil Storage

Vegetable oils can be stored for a long time if reasonable care is taken during storage. If the oil is to be stored for more than six months, the containers should be sealed with airtight caps, purged with nitrogen gas and stored in a cool, shaded location. Vegetable oils solidify at higher temperatures than diesel fuel, heated storage may be required in cold climates. Storage in plastic or coated steel drums is preferred.

On-Farm Ester Production

University of Idaho research has demonstrated that production of esters as a fuel in small on-farm plants is possible. Methyl ester of winter rape oil has been routinely produced at room temperatures. Research into using these esters as a fuel is encouraging and is still in progress.

Contamination of the fuel with catalyst is a constant risk of which potential users should be aware. The corrosive effect on engine components is potentially serious. However, long term testing with small engines has shown the ester fuel produced to date to be nearly equivalent to diesel.

To process 40 gallons of unmodified rapeseed oil, first dissolve 1.46 kg of potassium hydroxide pellets in 9 gallons of anhydrous methanol in a 55 gallon plastic container. Care must be taken in handling potassium hydroxide to avoid caustic burns. Polyethylene or polyvinyl chloride are suitable containers with good chemical resistance to potassium hydroxide.

With good stirring (1/4-hp motor is adequate), about 10 minutes is required for complete dissolution. Add the 40 gallons of filtered rapeseed oil with vigorous stirring and take care to completely exclude water. After approximately 4 hours at 70 F, stop agitation and allow the mixture to settle for at least 12 hours. Transfer the top ester layer to a polyethylene, conical bottom washing tank and sprinkle from the top with water for 20 hours at a rate of 75 gallon/hour to remove residual potassium hydroxide.

Direct Combustion of Rape Biomass

Rape meal is currently an unusable by-product of the rape oil extracted by the Agricultural Engineering Department at the University of Idaho. The high glucosinolate content of the meal from this variety makes it unsuitable as animal feed. The search for a use for this by-product led to the consideration of rape meal as a fuel in direct combustion processes.

Recent developments in the home heating industry enhance the prospect for the use of non-conventional fuels such as rape meal. The introduction of pellet burning stoves gives additional control over combustion processes and therefore allows the burning of materials with characteristics considerably different than those of wood or coal. A variety of configurations increases the likelihood of finding a combustion device with characteristics compatible with the unique properties of rape meal.

It is the intent of this study to evaluate the suitability of rape meal as a fuel in residential stoves. Specific objectives are:

1. Establish suitable test procedures and select equipment for the evaluation of rape meal as fuel for residential heating. A complete study would include determination of the following characteristics;

    a. Physical parameters of meal; density, moisture content, heat content.

    b. Composition of fuel; proximate (volatiles, fixed carbon, nonvolatiles, ash), biological (cellulose, lignin, other), and ultimate (elemental).

    c. Combustion efficiency.

    d. Emissions; particulates, carbon monoxide, sulfates, hydrocarbons.

2. Optimize combustion with respect to efficiency and emissions by;

    a. Controlling excess air and temperatures.

    b. Modifying fuel form or composition.

3. Establish the economic viability of using rape meal as a fuel.

The original form of the meal is not suitable for combustion in conventional stoves. Rape meal is expelled by the press in "flakes" less than 1 mm thick and up to 50 mm in diameter. Handling without breakage is impossible and trials showed that complete combustion of the resulting pieces was unlikely. These results led to the investigation of pelleting.

Rape meal pellets were produced by an agricultural feed pelleting facility. The pellets were cylindrical, 6 mm in diameter and up to 20 mm in length. Comparison with a commercial wood-based pellet showed that these dimensions were about 10% smaller than conventional fuel pellets. The rape pellets were also noticeably softer than the wood-based pellets. The bulk density of the rape meal pellets was 668 Kg/m3 (4% higher than the wood based pellets). A moisture content of 8.6% for rape and 6.7 for wood was determined.

Investigation of the fuel properties of the pellets began with the determinations presented in Table 1. The rape pellets have an 8% edge in energy content based on mass and a 12% advantage based on volume. The sulfur content of the rape pellets (1.18%) confirms the need for sulfate monitoring. The carbon/hydrogen ratios follow the same trend as the heat contents (0.161 for rape and 0.141 for wood).

Table 1. Fuel Properties of rape and wood pellets.

	Heat Content Btu/lb.	Composition %S	%C	%H
Rape Seed	11,735	0.69	58.39	9.20
Rape Pellets	8,934	1.18	46.54	7.48
Wood Pellets	8,242	0.02	47.55	6.75

The emissions were investigated first because of the mounting evidence that small stoves are significant contributors to air pollution. Early test results indicate that the rape fuel cannot be burned as cleanly as wood based pellets, but that its emissions are well within typical regulations, see Figure 1.

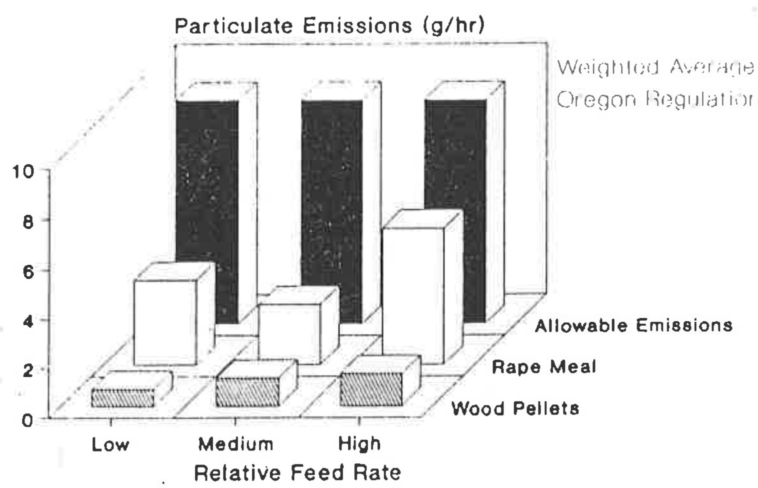

Figure 1. Particulate emissions from direct combustion tests.

Since the rape pellets produced by the feed mill were of poor quality (soft and crumbly) some effort was made to procure a better pellet in hope of improving feeding and burning characteristics. A commercial pelleting firm, which had developed a small punch type pellet mill, was interested in working with rape meal. They were not able to produce a sufficiently hard pellet with meal but reported that the addition of rape meal to some types of wood enhances the pellet density and surface hardness. They then produced about 50 lbs of blended pellets using 60% rape meal and 40% red fir shavings. These pellets have a very satisfactory composition and will be evaluated for burning characteristics, efficiency, and emissions.

Two, 6 hour trials were made with a 60/40 blend of rape and wood pellets. This mixture was easy to start and maintain. Clinker formation at the lower air ring, although an improvement over burning straight rape meal, was still quite evident.

Initial testing of rape meal as a fuel for direct combustion has led to the following conclusions:

1. Rape meal can be pelleted. The procedure does not substantially change the properties of the meal.

2 The energy content of the rape meal pellets justifies further investigation into the compatibility of these pellets and conventional stoves.

3. Combustion of rape meal pellets is possible and sustainable in the conditions common to most commercial pellet-burning stoves.

Rape Oil as a Diesel Fuel

Routine use of rape oil as a replacement for diesel fuel cannot yet be recommended; however, vegetable oil could be used as a diesel fuel substitute in time of fuel shortages or in time of emergency. In doing so, the engine operator should be aware that some engine damage may result. At first, the engine will appear to operate normally. Filter plugging, cold starting problems, injector coking, polymerization in the combustion chamber causing ring sticking and contamination of the lubricating oil causing reduced bearing life are all potential hazards. The high viscosity of the pure rape oil is thought to be largely responsible for many of these problems. Blending the vegetable oils with from 50 to 75 percent diesel fuel, to lower the viscosity, will reduce (but not eliminate) each of the problems mentioned above. Starting and stopping the engine on diesel and using the transesterified oil will also extend engine life.

Recent studies indicate that transesterified rape oil may be nearly equivalent to diesel fuel in terms of engine wear and combustion chamber deposits while developing slightly less power due to the lower heat of combustion.

Selecting a Vegetable Oil Type

Some of the vegetable oil types to consider as substitutes for diesel are sunflower, safflower, soybean, cotton, winter rape, canola and peanut. All of these vegetable oils have energy contents similar to diesel fuel, but are 11 to 17 times more viscous, which could result in injector pattern problems and is thought to be a least in part responsible for difficulties experienced with engine deposits. The vegetable oils have nearly the same specific gravity, but all are 7 to 9 percent heavier than diesel fuel. Table 2 lists some properties of a few vegetable oils and diesel fuel.

Table 2. SPECIFIC GRAVITY, VISCOSITY AND HEAT OF COMBUSTION OF SELECTED VEGETABLE OILS AND NO. 2 DIESEL (TYPICAL VALUES)

Oil type	Specific gravity	Kinematic viscosity	Heat of combustion
	(lb per gal)	(CST at 100 F)	(BTU/gal)
Sunflower	7.7	35.3	130,730
Linoleic safflower	7.7	32.3	130,964
Oleic safflower	7.7	42.1	139,715
Soybean	7.7	36.4	129,892
Cottonseed	7.6	37.4	121,793
Peanut	7.6	37.2	122,538
LEAR1	7.7	39.0	131,554
HEAR2	7.6	51.0	130,788
SSME3	7.3	4.8	124,286
WRME4	7.3	6.7	127,710
No. 2 diesel	7.1	2.9	138,250

1LEAR = Low erucic acid rapeseed
2HEAR = High erucic acid rapeseed
3SSME = Methyl ester of sunflower oil
4WRME = Methyl ester of winter rape oil

Fatty acid content of vegetable oil has a significant effect on carbon buildup in a diesel engine. Those oils with fewer double and triple bonds in their fatty acids, that is, those less unsaturated vegetable oils, have less tendency to polymerize. Vegetable oils in this category include high erucic winter rape, high oleic sunflower, safflower and peanut oils. The less desirable oils would include those derived from high linoleic safflower, high linoleic sunflower, soybean oil or linseed oil.

In a study in which oleic safflower and high linoleic safflower were compared in long term tests, the engines operated on oleic oils did have somewhat less engine deposits at the conclusion of the tests than did engines operated on the more unsaturated linoleic safflower, but both were high in deposits when compared to those operated on diesel.

Short Term Engine Performance

Nearly every study performed to date has shown that vegetable oil can be used as a direct substitute for diesel in short term tests limited only by the viscosity of the fuel. Short term tests show that power output, torque and brake thermal efficiency when engines are fueled with vegetable oil were equal or were close to test results from when the engine was fueled on diesel. Fuel consumption is generally slightly higher, reflecting the reduced energy content of the vegetable oil.

In a summary of 22 short term engine tests, conducted at 12 locations worldwide, in which vegetable oil was compared to diesel fuel, peak engine power on the vegetable oil fuels ranged from 91 to 109 percent of that on diesel fuel; in 16 of the 22 tests, peak power was equal to or exceeded test results from when the engines were operated on diesel fuel. The vegetable oils included in the tests were rapeseed, soybean, sunflower, peanut, palm kernel, jojoba, coconut, linseed and canola.

Long Term Engine Performance: Direct Injection Engines

While short term test results are almost always positive, longer term tests almost always lead to severe engine deposits, ring sticking, injector coking and thickening of the lubricating oil.

Injector coking is a problem reported in most long term engine tests with vegetable oils. A second major problem associated with vegetable oil use in direct injection engines is polymerization of the vegetable oil in the ring belt area causing the rings to seize. This is often associated with an increase in blow-by, a corresponding increase in the viscosity of the lubricating oil and resulting catastrophic failure of the engine. If vegetable oil is to be used without modification in direct injection diesel engines, it would need to be blended with diesel. The blend should not contain more than 25 to 50 percent vegetable oil. Whereas, if the vegetable oil is transesterified, it may completely replace diesel. However, reduced engine life may occur in both cases.

Long Term Engine Performance: Indirect Injection Engines

Fewer problems have been observed when using vegetable oils in direct injection engines -- those with pintle type injectors and precombustion chambers -- than with direct injection engines

(Fig. 2). However, because of fuel economy, the trend in engine design is away from indirect injection engines toward direct injection engines. Most tractors made in the United States are of direct injection design, while most of the small import tractors are indirect injection.

Even with indirect injection engines, the fuel should be a blend of diesel and vegetable oil of from 25 to 50 percent, lubricating oil should be closely monitored, and reduced engine life compared to operating on diesel alone should be expected.

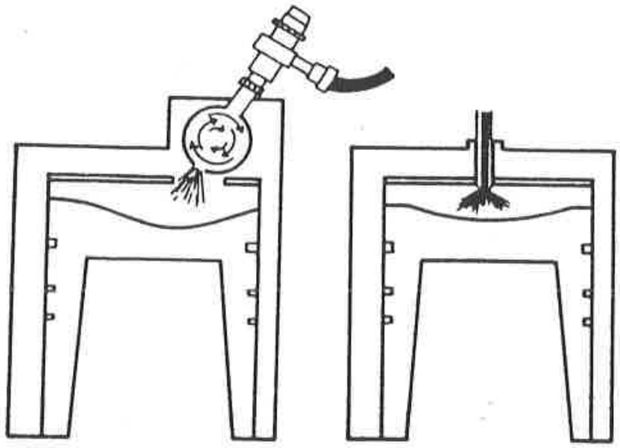

Figure 2. Schematic representation of a typical indirect injection engine (left) and direct injection engine (right).

Starting and Stopping on Diesel

Long term tests in small indirect injection diesel engines comparing starting and stopping on diesel with engines operated continuously on vegetable oil demonstrated that engines fueled with 100 percent diesel at start-up and shutdown operated 50 percent longer than engines started and stopped on the vegetable oil mixture. This study found that compression and power were within acceptable limits until over a very short period of time engine oil viscosity increased and the engines would no longer start.

Transesterification

Transesterification is the process of reacting a triglyceride, such as one of the vegetable oils, with an alcohol in the presence of a catalyst to produce glycerol and fatty acid esters. The ester has a viscosity approximately twice that of diesel fuel instead of 10 to 20 times, as is the case for the vegetable oils. Since viscosity of the fuel is of prime concern because of its effect on the diesel injection system and resulting spray patterns, the resulting reduction in viscosity greatly reduces engine operation problems.

Many researchers have reported success with vegetable oil esters in diesel engines. In most cases, engine deposits were reduced to what could be characterized as normal. Deposits from the ethyl ester were comparable in amount but slightly different in color and texture when compared to diesel. Methyl and butyl esters showed greater amounts of deposits in the top ring groove of the piston. All researchers report that engine wear was low, fuel consumption was increased but thermal efficiencies and power were nearly identical. The conclusion is that in an emergency the esters could be produced to operate direct injection engines as a complete replacement for diesel.

Some specific observations concerning use of esters are:

1. The pour points and cloud points are much higher than diesel indicating that the esters are much more susceptible to problems when used in cold weather.

2. Higher flash points make the esters somewhat safer to handle than diesel.

3. The cetane rating of the esters are comparable to or better than diesel.

4. The higher or gross heating value of the esters is approximately 11 percent lower than diesel on a mass basis. A corresponding reduction in engine power can be expected.

5. The specific gravity of the esters was somewhat higher than diesel; an average of .881 compared to .847 for the reference diesel.

6. The compatibility of the esters with the various materials with which they may come into contact in an engine is a concern. One research reports suggests a general tendency to harden all of the plastics with a subsequent change in their tensile strength. High density polyethylene and polypropylene are less affected than the others. Most rubbers were also affected. They suggest Viton-A as the most suitable construction rubber. Experience with tractor operation reveals a serious hostility of the ester towards paint, attacking it like a paint stripper. Any tendency to metal corrosion is very low. The introduction of esters as a fuel will necessitate the replacement of some fuel lines with a more compatible material. The adhesives in some fuel filters are also attacked by the esters, and they suggest that manufacturers should be consulted before they are used.

University of Idaho EMA Tests with Ester Fuels

A study recently completed at the University of Idaho assessed the potential of methyl ester of winter rapeseed oil on engine durability. The fuels used in this study were methyl ester of winter rapeseed oil, number 2 commercial diesel oil, and 50-50 winter rapeseed oil-diesel blend fuel.

A shorthand abbreviation using symbols as follows simplifies the discussion:

100RE = pure methyl ester of winter rapeseed oil;

100D2 = pure number 2 commercial diesel oil;

50WR-50D2 = half and half winter rapeseed oil and diesel oil blend fuel.

The winter rapeseed oil was extracted and the oil transesterified with methanol at the University of Idaho. The 50WR-50D2 used rapeseed oil and diesel blended 50 percent, by volume, of each without any further refining. Table 3 compares the properties of these test fuels.

TABLE 3. PROPERTIES OF THE FUELS USED IN THE TEST *

PROPERTIES	100RE	100D2	50WR-50D2
Cetane Rating	54.4	47.8	42.3
Flash Point (C)	83.9	80.0	89.4
Cloud Point (C)	-2.2	-12.2	-11.1
Pour Point (C)	-9.4	-28.9	-17.8
Viscosity (cs) @ 40C	6.0	3.2	10.2
@ 100C	2.39	1.26	3.13
Heat of Combustion kJ/kg (Gross)	35375.5	38536.6	37537.2
Density (kg/L)	0.874	0.852	0.879

* Data is reported by Phoenix Chemical Lab. Inc., Chicago, IL., based on samples submitted by the Department of Agricultural Engineering, University of Idaho.

The table shows that 100RE has a higher cetane number than either the 100D2 or the 50WR-50D2. The viscosity of the 100RE is 87.5 percent higher than the 100D2 but 41.2 percent lower than the 50WR-50D2 at 40 C. The gross value of heat of combustion of the 100RE is about 10 percent and 6 percent lower respectively than that of the 100D2 and 50WR-50D2 fuels. The flash point of the 100RE is also higher than that of the 100D2 but lower than that of the 50WR-50D2.

The principal equipment used in this research included:

-- diesel engines

-- data acquisition/control system

-- engine test stands.

Three Yanmar 3TN75E-S, 3-cylinder, 4-stroke, naturally aspirated, direct injection diesel engines were selected as the test engines. Each engine has a 75 mm bore, a 75 mm stroke, a displacement of 994 cc, a compression ratio of 17.6:1, and is rated at 14.5 kW at 3000 RPM. These engines were selected for the direct injection design, which is similar to that found in most diesel engines used in agriculture today.

A computer based data acquisition/control system consisting of an HP 85 microcomputer and a 3054 DL Data Logger scanned all three engine test stands one at a time continuously. The system capabilities include measuring engine load and speed, checking crankcase oil, load unit oil, fuel, exhaust temperatures, and controlling engine load, speed, and load unit oil temperature.

This research adopted the Engine Manufacturer's Association (EMA) Standard of 200-hour screening test to investigate the engine durability (EMA, 1982). This standard was created for alternative fuel research purposes.

Based on this standard, the test steps used for both replicates of this study are shown in Table 4.

Table 4. EMA ENGINE TEST CYCLES

LOAD SET	SPEED	TORQUE	POWER	TIME (min)
3	Rated	-----	Rated	60
2	85 %	Max.	95 %	60
1	90 %	28 %	25 %	30
0	Idle	0	0	30

The four load conditions used in this study were:

(1) Rated Condition -- Engines loaded to rated power of 14.5 kW at a speed of 2900 RPM for 60 minutes. The reason for using an engine speed at 2900 RPM instead of 3000 RPM for the rated condition was to eliminate the effect of the governor on the throttle setting.

(2) Maximum Torque -- Maximum torque at a speed of 2550 RPM for 60 minutes. This speed setting is 85 percent of the engine rated speed (3000 RPM).

(3) Low Load Condition -- 28 percent of the rated load was added. The engine was tested for 30 minutes under speed of 2700 RPM.

(4) Idle Condition -- Load removed from the engine and speed set at 1250 RPM for 30 minutes. Since the measuring system remained connected, the engines experienced very low loads.

Within the 200-hour test periods, all engines had run approximately 180 hours on the screening test. The remaining test time was accumulated on the auxiliary running time and on the engine variable speed test time described later. Three identical 3-hour cycles as described in Table 2 were run in the daily test.

A complete report of all the data from this test is not possible in this paper, but the summary comparison will be presented. To appraise the test fuels synthetically, a comprehensive evaluation formula was developed:

$$EV = k1*A+k2*B+k3*C+k4*D+k5*E+k6*F+k7*G+k8*H$$

where EV = The evaluated value. It is a number between 0 and 1.

k1, k2...k8 = The weight of each factor. In this study, all factors are considered to be equal in weight. The sum of these weights is 1. The individual weight is 0.125.

A, B...H = The evaluation factors. In this study, the factors are defined as:

A = Brake power

B = Thermal efficiency

C = Exhaust temperature

D = Carbon deposits on valves and pistons

E = Injector cokings

F = Lubricating oil dilution (viscosity)

G = Lubricating oil deterioration (metal concentration)

H = Wear of engine parts

When evaluating, each factor is compared separately. Set the highest performance value among the three test fuels to 1, the lowest to 0, and convert the rest to some point between 0 and 1 according to its value related to the highest and the lowest values. Determine all described factors for the test engines. Multiply those factor values by their weights. Add all of the weighted factor values together. The evaluated values are thus obtained. The higher the EV value, the better the fuel property. Table 5 shows the analysis results of the evaluation value.

As expected, the results show that the 100D2 possesses the best fuel property. In general, the fuel property of 100RE is a little worse than that of the 100D2. However, some of the particular properties in 100RE are somewhat better than those of the 100D2. Especially, the exhaust temperature condition in the 100RE fueled engines was much better than that in both 100D2 and 50WR-50D2 fuels. The carbon deposits on valves and pistons, the lubricating oil deterioration condition, and the wear of engine parts were found the best in the 100RE fueled engines. Additionally, the 100RE fuel also showed the most serious lubricating oil dilution problem among the test fuels.

TABLE 5. COMPREHENSIVE FUEL PROPERTY EVALUATION

FUEL	WEIGHT@ (k1...k8)	A	B	C	D	E	F	G*	H#	TOTAL
100RE	0.125	0.05	0.55	1	1	0.92	0	1	1	0.69
100D2	0.125	1	1	0.12	0.71	1	1	0.95	0.63	0.80
50WR-50D2	0.125	0	0	0	0	0	0.48	0	0	0.06

* 0-hour data were not included in the comparison. The concentration of iron was lessened 10 times to avoid comparing the lubricating oil deterioration based on the iron mainly since it was much higher than the others.

\# The wear rate of ring end gap was lessened 10 times for avoiding the comparison based on it mainly.

@ In this case all factor weights equal to 0.125.

The evaluation revealed that the 50WR-50D2 had the poorest fuel property. All evaluated factors except the lubricating oil dilution (viscosity) showed the lowest property values. The factors of thermal efficiency, carbon deposits on valves and pistons, injector cokings, lubricating oil deteriorations, and wear of engine parts were much worse than those for the 100RE and 100D2 fueled engines. This indicates that compared with 100RE, 50WR-50D2 is not a suitable fuel substitute for diesel engine use.

Potential Production of Vegetable Oil in Comparison to Diesel

U.S. diesel consumption in agriculture is estimated at 3.3 billion gallons which would require 3.6 billion gallons of vegetable oil to replace it on an equal energy basis. Ten to 15 percent of total U.S. cropland would be required to produce the needed vegetable oil. In 1981, 19 percent of the U.S. cropland was planted to vegetable oil crops. Currently the U.S. is the largest oilseed producing nation (35% of the world production in 1980-81). Approximate U.S. oilseed production is shown in Table 6.

Table 6. U.S. production of vegetable oils.

CROP	HARVESTED HECTARES	PERCENT OIL	LITERS OIL	LITERS PER ha	% OF U.S. CROPLAND
	(000)		(000)		
Soybeans	26,987	18	10,780,501	402	14.70
Sunflower	1,414	40	809,896	571	.80
Cottonseed	5,592	17	631,145	112	3.10.
Peanuts	602	31	601,823	992	.30
Total	34,595		12,094,365		18.90

Conclusions - Rape Oil as a Diesel Substitute

A few specific conclusions regarding operating an engine on vegetable oil are:

1. Use vegetable oil for as short a time as possible and only when good quality diesel is not available.

2. Blend the vegetable oil with diesel to reduce the viscosity.

3. The choice of vegetable oil can have an effect on engine life. Use of the more saturated vegetable oils such as high oleic safflower or peanut oil or high erucic acid rape oil in preference to the more unsaturated oils such as high linoleic safflower or soybean oil is recommended.

4. Clean the injectors if engine performance appears to degrade.

5. Check engine oil viscosity regularly, at least each 8 hours of operation. Change oil more frequently than the

normal oil change interval recommended by the manufacturer. Oil change intervals of 50 to 75 hours may be desirable.

6. It may be necessary to add an additional in-line filter in the fuel line. Filter plugging is a common problem. A fuel additive such as DuPont FOA-2 has been found to be effective in reducing filter plugging.

7. Do not idle the engine for long periods and do not lug the engine any more than necessary. Both of these practices allow raw vegetable oil to accumulate in the ring belt area causing ring sticking and contamination of lubricating oil. Operate the engine in the 50 to 90 percent power range as much as possible.

8. If practical, add an additional tank and start and stop the engine on diesel. Switch to diesel about 5 minutes before shutdown to purge the vegetable oil blend from the fuel system and from the combustion chamber. Allow the engine to warm-up on diesel before switching to the vegetable oil blend.

9. Avoid cold weather operation with vegetable oils or install tank and line heaters to extend cold weather operation. Vegetable oils solidify at much higher temperatures than diesel.

10. The vegetable oil molecule can be altered in a chemical reaction to form the ester. These esters have been found to be nearly equivalent to diesel. However, the production of esters is not yet thought to be sufficiently developed for on-farm use. It may also add considerable cost to the vegetable oil fuel unless a market for the by-products can be found. The esters are a very desirable emergency fuel substitute for diesel when they are available.

Disclaimer Statement

This report contains a summary of research results. This report is not to be construed as a recommendation for the use of any alternative fuel mixture mentioned. The engine operator is responsible for all decisions concerning use of alternate fuels.