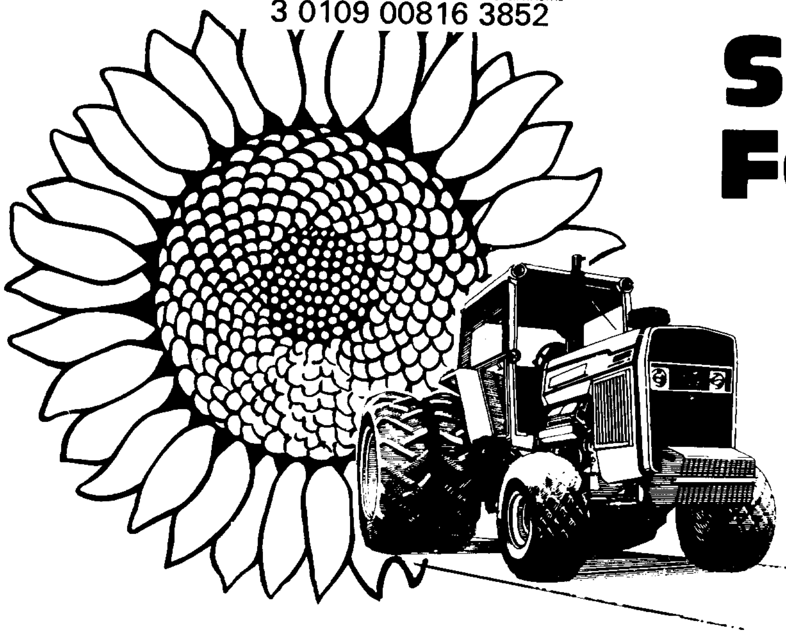
APRIL 1981

CIRCULAR AE-735



Sunflower For Power!

Vern Hofman
Extension
Agricultural
Engineer

Ken Kaufman
Assistant Professor
Agricultural
Engineering

Delmer Helgeson
Professor,
Agricultural
Economics

W. E. Dinusson
Professor
Animal Science

SUNFLOWER FOR POWER

INTRODUCTION

Sunflower oil as a fuel for diesel engines is receiving considerable attention. Although diesel engines will run on sunflower oil (SFO), many questions remain to be answered before it can be recommended for use in farm engines. Tractor manufacturers will not guarantee their engines if vegetable oil is used, but this may change as research progresses. This publication includes information on test work done on extraction and use of sunflower oil in engines at NDSU and other institutions and contains additional information accumulated since the previous circular "Sunflower Oil as a Fuel Alternative" was published in 1980.

SUNFLOWER OIL PROPERTIES

Sunflower oil has several physical properties that are similar to diesel fuel, but the differences may be enough to cause problems. The main differences are shown in Table 1. The energy content of sunflower oil is about 10,000 BTU/Gal less than diesel fuel. In internal combustion engines, power output is directly related to the energy content of the fuel. If the energy content is lower, power output (HP) and fuel efficiency (HP-HR/Gal) are reduced. This trend is shown in the engine tests. Increasing the amount of fuel injected should increase horsepower.

The cetane number of sunflower oil is lower than diesel fuel. This may cause hard starting and ignition problems such as engine knock. Cetane number is an indicator of a fuel's combustion quality. A low cetane fuel does not burn as fast (or delays ignition for a greater period of time) as a higher cetane fuel. Cetane number of sunflower oil can be increased by mixing with diesel fuel or using cetane improvers such as amyl nitrate or cyclohexanol nitrate. The American Society for Testing Materials (ASTM) specifies a minimum cetane number of 40 for high speed diesel engines.

Viscosity is an indicator of the flowability of a liquid. A high viscosity number indicates a thick liquid. Sunflower oil is about 14 times thicker than diesel fuel at 100°F and is about 30 times thicker at 32°F which may slow the flow of fuel through fuel lines and filters. Also, a high viscosity liquid may increase

Acknowledgement to: Dr. George Pratt, Chairman, Agricultural Engineering Dept., L. Schaffner, Ag. Economics, J. Lindley, Ag. Engineering, P. Ramdeen, Grad Student, M. Marohl, Grad Student, Mariusz Ziejewski, Foreign Exchange Scientist.

COOPERATIVE EXTENSION SERVICE

the pressure in the injector pump above its design limits. A high viscosity fluid will not atomize as easily as a lower viscosity liquid and cause poor combustion in the engine and problems with starting in cold temperatures. Mixing sunflower oil and diesel fuel together will result in a fuel blend which has a viscosity between that of sunflower oil and diesel fuel. Figure 1 shows the viscosity of sunflower oil, diesel fuel and blends at various temperatures.

Table 1. Fuel Properties

	Lb/Gal	BTU/Lb	BTU/Gal	Cetane No.	Viscosity $mm^2/sec.$ 100°F.	Viscosity $mm^2/sec.$ 32°F.
No. 2 Diesel	7.07	20,000	140,000	48	2.4	6.4
50/50 Sunflower Oil/ #2 Diesel Fuel	7.38	18,367	135,000		9.6	34.5
Sunflower Oil	7.70	16.883	130.000	37	34.3	187.7

Vegetable oils are large molecules which may burn poorly. After long-term use, they may form deposits in the injector nozzles and combustion chamber, cause sticking of piston rings, and result in crankcase oil polymerization (thickening).

There are physical differences between various types of vegetable oils. One oil may perform differently than another in power output and deposits remaining in the engine. One report on a 50:50 mix of soybean oil and diesel fuel caused considerable buildup of sludge in the crankcase oil. This was due to blowby into the crankcase. If this occurs, poor lubrication and eventual engine failure will result. Changing the oil more frequently should reduce this problem. Also, engines having considerable blowby should not be operated on vegetable oil. These would include new engines that do not have rings seated properly or older badly worn engines.

The NDSU tests on a Ford 7000 have not shown any buildup of undissolved solids in the crankcase after approximately 150 hours of operation on various mixtures of sunflower oil and diesel fuel.

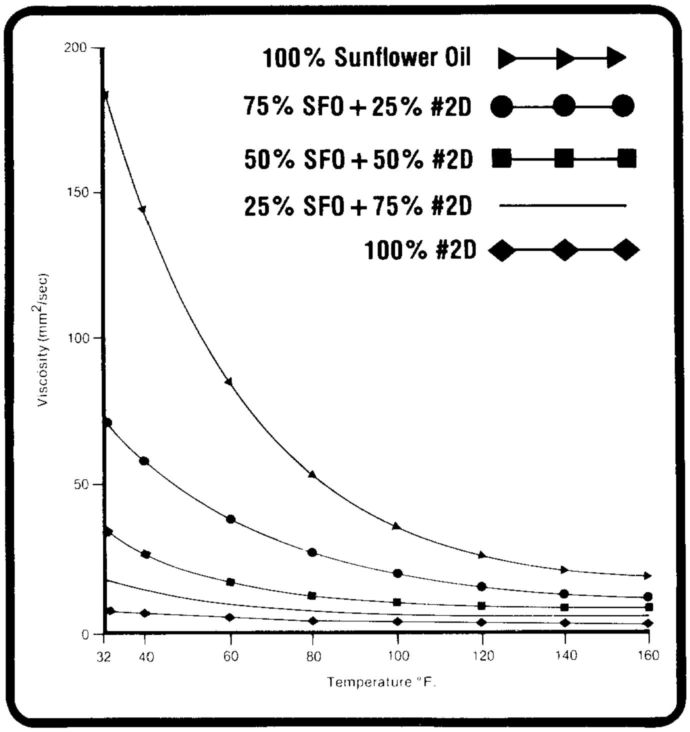


Figure 1. Viscosity of Sunflower Oil, Diesel and Blends

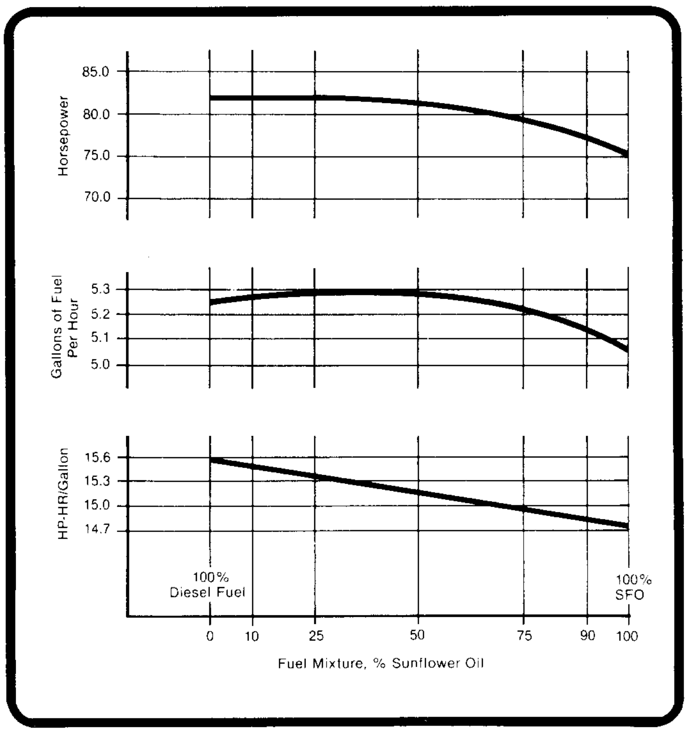


Figure 2. NDSU Sunflower Oil Engine Tests Using a Ford 7000 Tractor.

DIESEL ENGINE TESTS

Dynamometer tests have been conducted using a Ford 7000 tractor engine. It is a turbocharged 4-cylinder, 256 cubic inch diesel engine with a compression ratio of 16.5 to one, rated at 83.49 PTO HP on Nebraska Tractor Test 1093.

Short-term performance tests of less than 30 minutes using various mixtures of sunflower oil and diesel fuel have been run with the engine. The oil was extracted from sunflower seed, settled and filtered through a 5 micron filter. This would be considered a crude oil. Further processing would be needed to produce cooking oil.

Figure 2 shows the results of the tests. The percent of sunflower oil in the mix is shown on the bottom of the graph. The percentages of sunflower oil in the fuel increases from all diesel fuel to all sunflower oil as one moves from left to right on the graph. The top curve shows the full load horsepower of the Ford tractor while running on mixtures of diesel fuel and sunflower oil. Seven mixtures of fuel ranging from all diesel fuel to all sunflower oil were used. When 100 percent sunflower oil was used to fuel the engine, the horsepower decreased approximately 8.5 percent. The middle curve shows the fuel consumption of the engine in gallons per hour. Fuel consumption during the tests decreased about 3.2 percent on 100 percent sunflower oil. The lower curve shows the HP-HR/Gal which is a measure of engine efficiency. This is comparable to miles per gallon in highway vehicles. It is an indication of how much work is accomplished while using a given volume of fuel. The efficency of the engine decreases 5.1 percent when using all sunflower oil as compared to diesel fuel.

It must be remembered these are short-term tests and may not be a true indicator of long-term use. Long-term tests are in progress and should indicate any effect on engine life.

Trials have also been made using methyl ester as fuel. The horsepower output is very similar to burning diesel fuel and the engine seems to respond very well. This fuel can be produced from sunflower oil by breaking the sunflower oil molecule down to a size similar to diesel fuel. The diesel fuel molecule consists of a hydrocarbon chain of 16 to 20 carbons. Reducing the size of the sunflower oil molecule reduces its viscosity to a value similar to diesel fuel. A chemical conversion is needed to remove the glycerol molecule from the sunflower oil molecule. Equipment, alcohol, a catalyst and heat are needed to cause the reaction to occur. One disadvantage of methyl ester is that it tends to crystallize at temperatures between 30°F. and 40°F. This means that it could only be used in warm weather or with a fuel heater.

SUNFLOWER OIL EXTRACTION

The oil extraction process used by the Agricultural Engineering Department is strictly mechanical. The only preprocessing necessary is cleaning the foreign matter from the seed with a fanning mill. Seed directly from the combine can be used, but dirty oil results. A cleaning operation is necessary to remove metal and stones from the seed. A magnet should be installed ahead of the expeller to remove all metal.

The screw expeller exerts pressure on the seed to squeeze about 3½ gallons of oil per hour from about 95 pounds of seed. The expeller is powered by a three HP electric motor and extracts about 70 to 75 percent of the oil in the sunflower seed assuming the seed contains 40 percent oil and sunflower oil weighs 7.7 pounds per gallon. This produces about 28 to 30 pounds of oil from 100 pounds of seed. In larger units, heating of the seed to approximately 250°F prior to squeezing may increase the extraction rate up to about 80 percent. The oil extracted from the clean seed contains considerable seed particles which settle to the bottom of the tank after a few days. After the particles settle, the oil is skimmed off and run through the filter.

The filter unit is powered by a ½ horsepower electric motor and will process about 34 gallons per hour. The crude oil that results has been used in the test engines.

The average sunflower production in North Dakota is about 1,350 pounds per acre. If 75 percent of the oil in the seed can be extracted mechanically, the oil yield is about 53 gallons per acre. The on-farm fuel required to produce one acre of sunflower or small grain in North Dakota is about 5 to 6 gallons per acre. Under these conditions, one acre of sunflower can produce fuel to grow 8-10 acres of small grain or sunflower. It must be remembered that these are on-farm fuel requirements. More energy is needed to produce the fertilizer, chemicals, and machinery manufacturing off the farm. Indirect machine is the energy needed to manufacture the farm equipment. The total crop energy requirement is shown in Figure 3. All energy requirements are shown in gallons of diesel fuel equivalents. The total production energy requirement is approximately 18.7 gallons per acre. Table 2 lists the BTU energy inputs and returns from the oil and meal for an acre of sunflower.

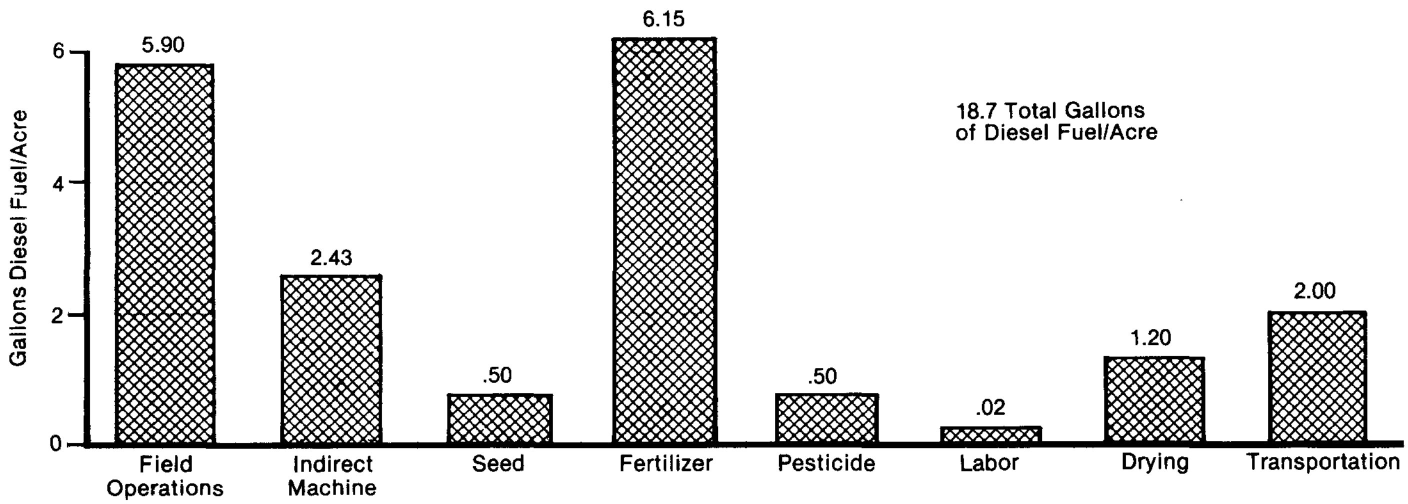


Figure 3. Sunflower Production Energy Requirements (Gallons Diesel Fuel Equivalent/Acre)

Table 2. Energy Inputs and Returns From an Acre of Sunflower

	BTU/Acre
Energy Input	
Sunflower Production - 18.7 GPA at 140,000 BTU/Gal	2,618,000
Sunoil Extraction - 53 GPA requiring 4,000 BTU/Gal	212,000
Total	2,830,000
Energy Returns	
Sunflower Oil - 53 Gallons/Ac. @ 130,000 BTU/Gal	6,890,000
Sunflower Meal - 942 Lbs/Ac. valued at 8,900 BTU/Lb	8,383,800
Total	15,273,800

$$\text{Ratio of } \frac{\text{Output}}{\text{Input}} = \frac{15{,}273{,}800}{2{,}830{,}000} = 5.4{:}1$$

Sunflower is an excellent producer of energy. It produces 5.4 BTU's of energy for every BTU consumed.

The screw expeller being used by North Dakota State University is as follows: CeCoCo Hander Unit built by Chuo Boeki Goshi Kaisha, P.O. Box 8, Ibaraki City, Osaka, Japan. The western U.S. distributor is: George Brocke & Sons Inc., Box F, Kendrick, Idaho 83537. The other units with similar capacity are available from: Simon-Rosedowns, Ltd., Cannon St., Hull, England HU2 0AD and S.P. Engineering Corp., P.O. Box 218, 79/7 Latouche Road, Kanpur, India. The distributor for Simon-Rosedowns is: Chuck's Farm Supply, New Salem, North Dakota 59563. These are the only makers of small screw expellers that the authors are currently aware of. Other expellers may be available and it is not intended that this is an endorsement of these units. The names and addresses are mentioned so interested individuals may make direct contact to the manufacturers.

ON-FARM SUNFLOWER OIL EXPELLER COSTS

In 1980, the average farm in North Dakota consumed about 3,665 gallons of diesel fuel on 1,040 acres. Cost estimates have been made for farm processing of sunflower oil to replace the diesel fuel with a screw expeller with a capacity of approximately 95 pounds of seed per hour producing slightly over 3.5 gallons of oil per hour. Two cost estimates are presented. The second assumes no cost for buildings or labor. It assumes a building is available on the farm and that the operator has no other use for his labor for part of the year. The labor requirement is about 1,160 hours or about 116-10-hour days. A 500 square foot building is required to house this squeezing equipment. The processing area requires a hopper-bin, seed cleaner, expeller, oil filter, oil storage tank and a furnace. Table 3 shows the investment in buildings and equipment needed for a small plant. Table 4 shows the two cost estimates for processing

Table 3. Investment in Building and Equipment for On-Farm Processing of Sunflower Seed

Item	Dollars
Building	
500 square foot steel processing	6,935[a]
Meal storage bin	2,280[a]
Total building investment	9,215
Equipment	
Hopper bin (311 bushel)	1,760[a]
Crusher (94 lbs. seed/hour or 3.56 gals. oil/hour)	4,500[b]
Filter (270 lbs. oil/hour)	3,800[b]
Seed cleaner	1,000[a]
Oil storage tank	1,500[a]
Furnace[a]	1,200[a]
Total equipment investment	13,760
Total investment in buildings and equipment	22,975

[a] *Local Price*
[b] *January, 1980, cost estimate by CeCoCo Chuo Boeki Goshi Kaisha Company of Japan FOB Seattle, Washington*

Table 4. Estimated Cost of Processing 3,665 Gallons of Sunflower Oil Using a Small Press[a]

Expense Item	Scenario 1[b] Dollars	Scenario 2[c] Dollars
Variable Expense		
Equipment repair	780	780
Electricity	185	185
Fuel oil	345	345
Building maintenance	184	184
Total Variable Cost	1,494	1,494
Fixed Cost		
Building depreciation	369	---
Equipment depreciation	415	415
Interest on bldg. investment	461	---
Insurance on bldg. & equip.	688	688
Operator labor, 1,158.5 hours	5,792	---
Total Fixed Cost	7,780	1,128
Sunflower seed, 966.46 cwt. @ $10.40	10,051	10,051
Credit for 34.21 tons of meal @ $135/T.	4,618	4,618
Total cost to process 3,665 gallons of sunflower oil	14,707	8,055
Cost per gallon of sunflower oil	4.01	2.20

[a] *The small press will crush 94 pounds of sunflower seed per hour.*
[b] *Scenario 1 includes all costs including a cost for buildings and operator labor.*
[c] *Scenario 2 assumes the buildings are available with no other use and no charge is made for the operator's labor.*

3,665 gallons of sunflower oil. The estimates are based on sunflower seed costing $10.40 per hundredweight. The results show that a gallon of sunflower oil costs $4.01 when all costs are included and $2.20 when labor and building costs are excluded. A larger processing operation should decrease the cost per gallon of oil produced. Sunflower oil looks to be less efficient than diesel fuel, so a small increase in gallons of oil may be required to farm the same acreage.

Another way to compare costs of fuels is cost per 100,000 BTU's of energy. Table 5 is a cost comparison of commonly used fuels on North Dakota farms.

Table 5. Cost Comparison Fuels (March 1981)

Fuel	Cost per Gallon Dollars	BTU/Gal.	Cost/100,000 BTU Dollars
Gasoline	1.20	125,000	0.96
Ethyl Alcohol (200 proof)	1.75	84,000	2.08
#2 Diesel Fuel	1.10	140,000	0.78
Sunflower Oil (Crude)	2.20	130,000	1.69
Propane	.70	92,000	0.76

From the chart, the most expensive fuel is alcohol, the next most expensive fuel is sunflower oil. Price is one of the major obstacles to the use of these alternate fuels as well as the effect of long-term use in an engine.

FEED VALUE OF SUNFLOWER SEED AND MEAL

Sunflower seeds (40 percent oil) can be used to a limited extent in rations fed to beef cattle if free of mold. Results suggest that about 3 lb. per head daily can be fed without affecting gain and feed efficiency. This amounts to about 1 to 1¼ lb. daily of the highly unsaturated oil. Feeding 5 lbs. of seed per head daily results in reduced feed intake, reduced gain and reduced feed efficiency. Feeding in excess of 2 lbs. of oil daily (from screw press residue) to 750-lb. steers resulted in loss of weight and scours. The oil, when fed in excess, also seems to reduce the digestibility of protein and fiber in the rations.

Whole sunflower seeds in swine rations should constitute less than 10 percent of the ration. Higher levels result in "soft pork," and inferior carcass quality.

Three types of sunflower oil meals have been available: a 42 percent protein meal from dehulled seed; a 34 to 35 percent protein meal from partially dehulled seed; and a 28 percent protein meal from seeds with hulls. Each of these meals are both press and solvent extracted and usually have less than 2 percent residual oil.

In experiments with cattle and sheep, the sunflower oil meals have given results similar to soybean oil meal when substituted on an equal protein basis. The energy value of the sunflower oil meals are less than that of soybean oil meal because of the added fiber content when some or all of the hulls are included.

In swine rations, the limiting factor in the sunflower oil meal is the lack of the amino acid, lysine. In the high protein meals, 42 percent or more crude protein from dehulled seeds, the lysine content is only 1.5 percent compared to about 3 percent in soybean oil meal. In the 34 percent protein meal, the lysine is about 1.2 percent and in 28 percent meal is about 1.0 percent lysine.

Substituting sunflower oil meal for ⅓ or ⅔ of the soybean oil meal and adding synthetic lysine to equal the lysine provided by the soybean oil meal gave very similar results in barley based rations for growing-finishing rations for swine. Substituting all the soybean oil meal with sunflower oil meal, even with the lysine additions, gave more variable results. However,the differences were small.

In corn based rations for swine, ⅓, ⅔ or all the soybean oil meal could be replaced if lysine was added to make up the difference between the sunflower oil meal and soybean oil meal rations.

Lysine supplement is expensive; when all the soybean oil meal was replaced in corn-based rations the cost of the lysine was equal to or greater than the cost of the sunflower oil meal supplied to furnish the necessary protein. In using sunflower oil meal in swine rations, calculate costs to determine how much sunflower oil meal can be used economically.

In ruminant rations, calculate costs on price per unit protein basis because lysine is not critical. For example, there are 680 lbs. of protein per ton of 34 percent protein sunflower oil meal. At $130 per ton, the cost per pound of protein is $0.19 ($130 ÷ 690 lbs.). For soybean oil meal at $300 per ton and 44 percent protein, the cost per pound of actual protein is $0.34 ($300 ÷ 880 lbs.)

SUNFLOWER MEAL AND BIOMASS

A great deal of attention is being focused on biomass from agricultural crops. Biomass usually includes all agricultural plants such as cereal grains, plant residues and weeds. Most of the grains and dry plant material contain about 7,000 to 8,500 BTU per pound of dry material. Depending upon the price of the material and a means of utilizing biomass, a sizeable amount of energy could be available for heat.

Sunflower meal that contains a small amount of oil has an energy content of 8,900 BTU/Lb. If all the oil is removed, sunflower meal contains 8,500 BTU/Lb. Oil increases the energy content of the meal. Sunflower with its high energy content could provide considerable heat in a furnace. However, few biomass furnaces are commercially available. On a small scale, an airtight wood stove could be used, but when a loose, fluffy material is used the stove would need to be refilled frequently. Coal furnaces with stoker feed appear to be a way of utilizing pelleted or briquetted biomass and will probably work for oil seed and cereal grains as well. Another problem with biomass is disposal of the ash. In some cases, as much as 20 percent of the fuel may be ash.

Table 6 is a fuel cost comparison chart showing the relative heating values of fuels and biomass. The chart is arranged so the equivalent price or each fuel based upon a specified efficiency is located directly above or below each other. For example, if the price of #2 fuel oil is $1.00 per gallon, the equivalent cost is 3.5¢/KWH for electricity, 71¢/gal. for propane, $93.00 per ton of coal, $3.00 per bushel for hard red spring, or $7.41 per cwt. for sunflower seed.

FUEL FOR AMERICA'S FARMERS

Every so often someone says farmers should go back to the "Good Old Days" and use horses in their farming operation. That sounds good from the aspect of conserving diesel fuel but is not practical. Horses require a tremendous amount of feed so they can produce work. Studies in the 1920's determined that about 33 percent of the land area was needed to produce feed for horses. Also, if horses were to become the power source on farms, a tremendous increase in manpower would be needed to care for the horses. Estimates state that approximately 61 million horses would be needed to produce the crops grown in 1975. The number of horses in the United States is placed at about 3 million, so a number of years would be needed to produce the needed animals. The 61 million horses would need about 31 million workers to take care of them. Presently, there are 4 million workers on farms, so 27 million workers would need to be shifted from the industrial labor force to agriculture. If sunflower oil becomes a usable fuel, about 10 percent of the land planted to sunflower would replace the on-farm diesel fuel needs.

U.S. farmers used about 3.4 billion gallons of diesel fuel in 1979. If sunflower oil were capable of replacing diesel fuel, about 3.6 billion gallons would be needed considering sunflower oil is 5.1 percent less efficient than diesel fuel. This would require almost 68 million acres based upon a sunflower yield of 1,350 lbs/acre and an oil extraction efficiency of 75 percent. Between 3 and 4 million acres of sunflower were harvested in 1980. Sunflower as well as other oil crops could see tremendous growth in production if the oil can be used as fuel.

Table 6. Fuel Cost Comparison Chart

Heating Efficiency	Equivalent Price of Each Fuel							
100%	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	Electricity ¢/KWH
70%	.72	.86	1.01	1.15	1.29	1.43	1.58	1.72	#2 Fuel Oil $/Gal.
75%	.55	.66	.77	.88	.99	1.10	1.21	1.32	Natural Gas $/Therm
75%	.50	.61	.71	.81	.91	1.01	1.11	1.21	Propane $/Gal.
65%	66.00	80.00	93.00	107.00	120.00	133.00	147.00	160.00	Coal (Lignite) $/Ton
65%	88.00	106.00	123.00	141.00	159.00	176.00	194.00	211.00	Wood $/Cord
75%*	.37	.44	.52	.59	.66	.74	.81	.88	Alcohol 160 Proof $/Gal.
65%*	5.30	6.35	7.41	8.47	9.53	10.58	11.64	12.70	Sunflower $/Cwt.
65%*	85.00	102.00	119.00	137.00	153.00	169.00	186.00	203.00	Sunflower Oil Meal $/Ton
65%*	62.00	74.00	86.00	99.00	111.00	124.00	136.00	149.00	Straw $/Ton
65%*	2.14	2.57	3.00	3.42	3.86	4.28	4.71	5.14	HRS Wheat $/Bushel
65%*	1.65	1.98	2.30	2.65	2.97	3.28	3.62	3.95	Barley $/Bushel
65%*	1.90	2.28	2.66	3.04	3.42	3.80	4.18	4.56	Shelled Corn $/Bu.

**Estimated Heating Efficiency*

OTHER RESEARCH RESULTS

The Republic of South Africa Department of Agriculture and Fisheries has done considerable work with sunflower oil as a fuel. Performance tests have been conducted on five different makes of tractors —nine models in all. The tractor makes are Fiat, International Harvester, John Deere, Landini and Massey Ferguson. Their tests found that maximum engine power on sunflower oil was down by 3 percent and fuel consumption was up by 10 percent.

In another test conducted in South Africa, a Ford 7000 completed 100 hours of operation at maximum power using 100 percent sunflower oil. The load on the tractor was produced by a PTO dynamometer. The tractor was then operated in the field for another 1,004 hours on a mixture of 20 percent sunflower oil and 80 percent diesel fuel. At the end of this period, the tractor showed a power loss of 8 percent. The injector nozzles were replaced and the power loss was reduced to 4 percent. The tractor was again connected to a PTO dynamometer and operated at a 70 percent continuous load for another 278 hours on a mixture of 20 percent sunflower oil and 80 percent diesel fuel. At this time, exhaust smoke increased noticeably. It was found that the orfices in the injector nozzles had started to carbon up. The engine was disassembled and was found to be similar in appearance to an engine burning diesel fuel. There were no combustion chamber deposits or gumming while using sunflower oil.

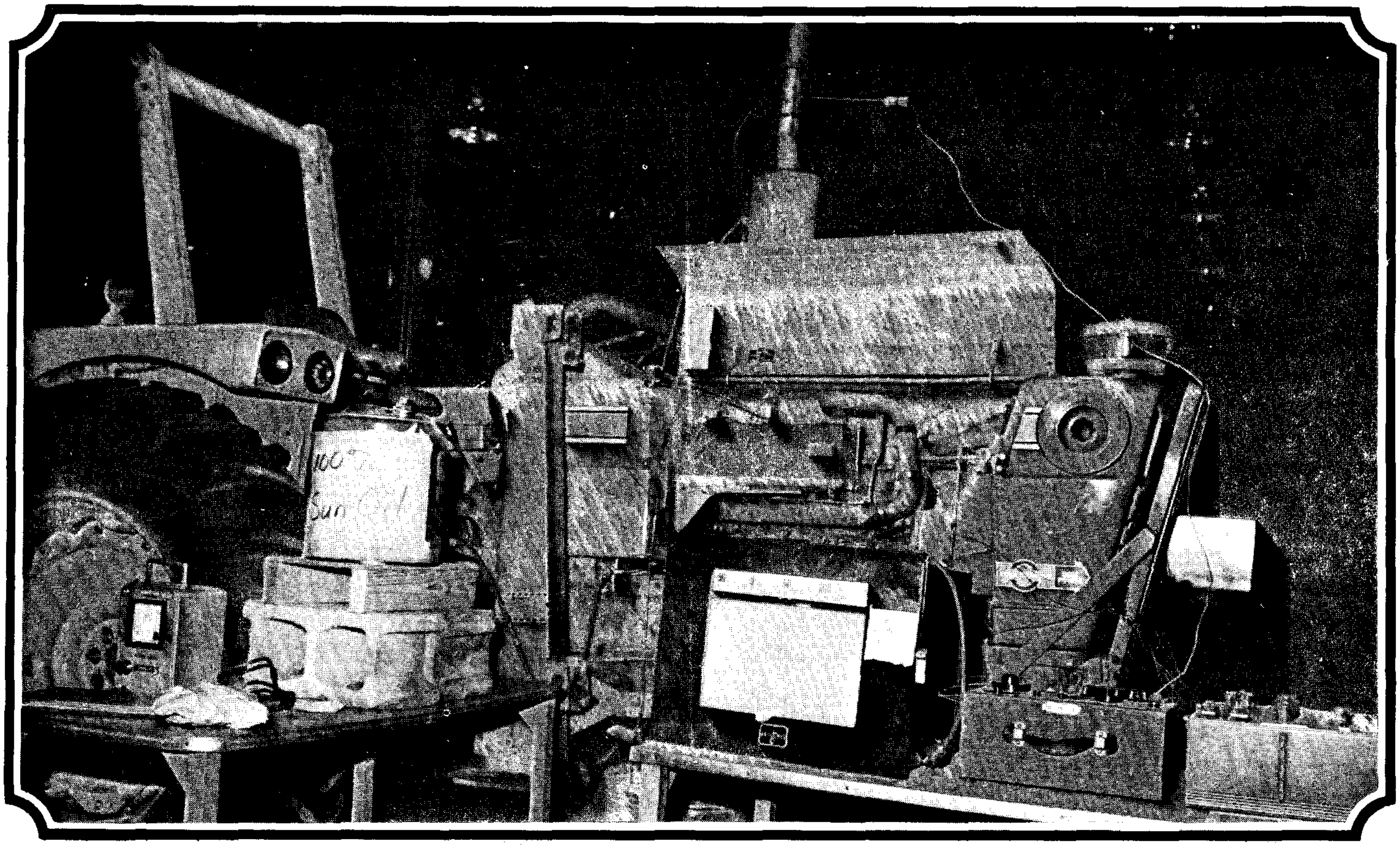
Another test tractor was operated at a 70 percent load on a dynamometer with a mixture of 80 percent sunflower oil and 20 percent diesel fuel for 300 hours. The engine experienced piston ring sticking, deposits on the injector tips and crankcase oil dilution. A buildup of solids was found in the crankcase which was due to depletion of the anti-oxidant additives in the oil from the use of sunflower oil as a fuel.

The South Africans have also run preliminary tests using methyl ester as a fuel for approximately 100 hours at 80 percent power. The results indicate a very good performance, less exhaust smoke than diesel and increased engine thermal efficiency.

The Commonwealth of Scientific and Industrial Research Organizations, Victoria, Australia is researching vegetable oils for use in diesel engines. Their findings show that power output and efficiency were close to diesel fuel. Fuel consumption was 11 percent higher due to the lower energy content of the sunflower oil. Carbon buildup occurred around the injector nozzles after 100 hours of operation due to the higher oil viscosity which altered the spray pattern and caused poor combustion. Injector bypass flow was ½ to $\frac{1}{10}$ that of diesel fuel which could reduce injector cooling and lubrication. Carbon buildup around the injector nozzle decreased engine power, increased exhaust smoke, and caused eventual engine misfire.

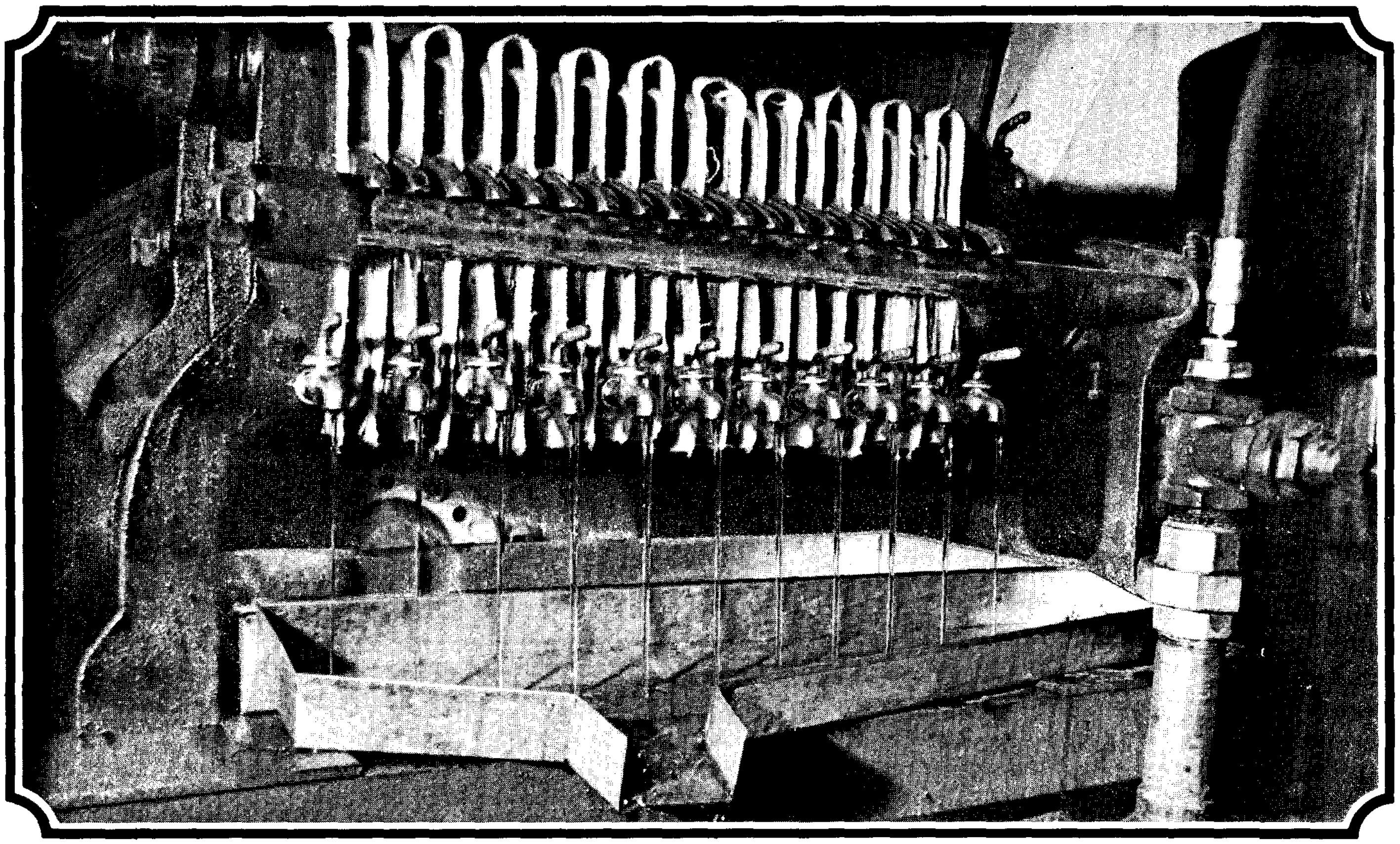
★ ★ ★

Short-term engine tests using mixtures of diesel fuel and sunflower oil and pure sunflower oil have been run on this 7010 Allis-Chalmers tractor. The engine is a turbocharged six cylinder, 301 cubic inch displacement with 16.25 to 1 compression ratio. The test results are very similar to the Ford 7000.

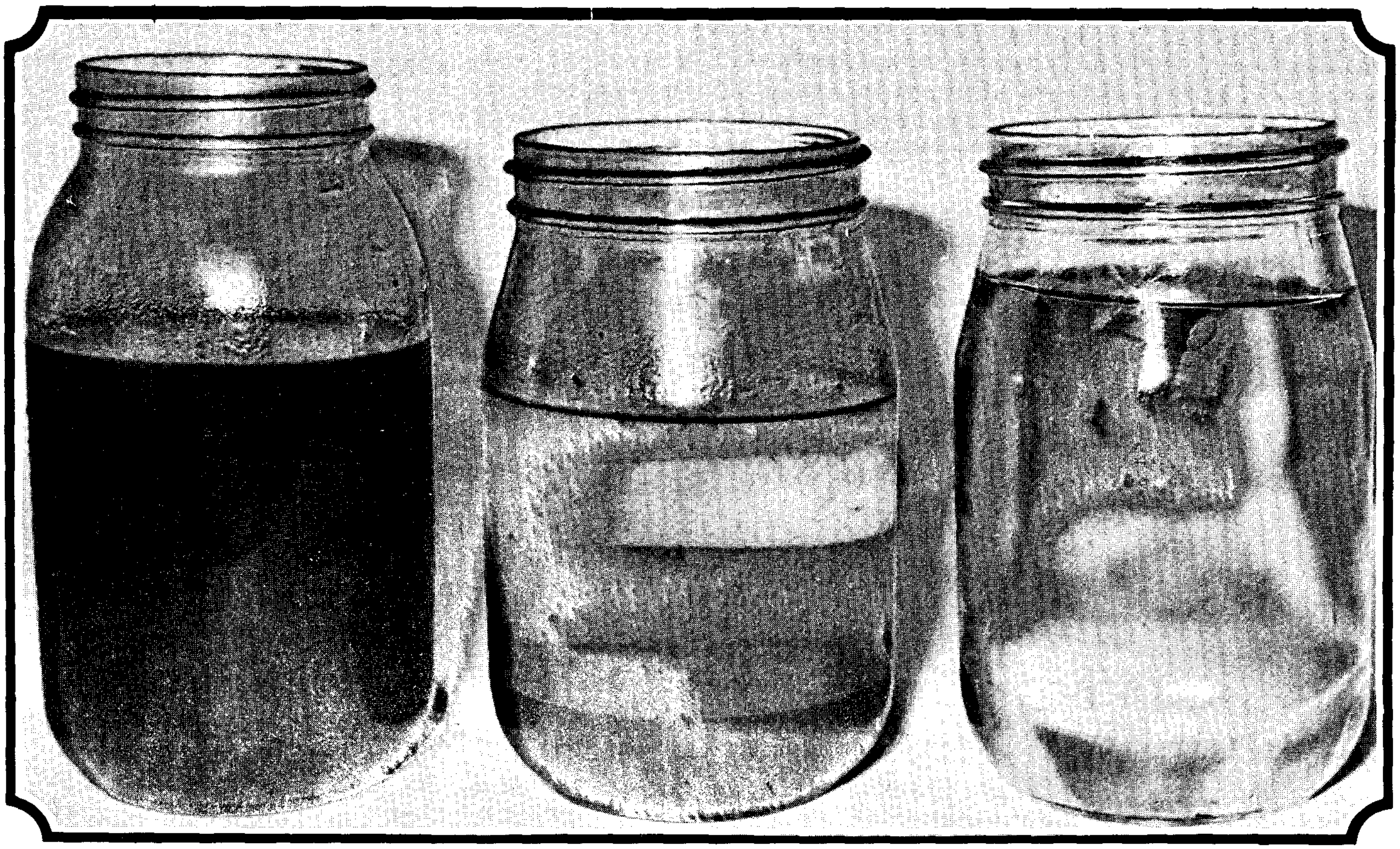


Short-term engine tests using mixtures of sunflower oil/diesel fuel and 100 percent sunflower oil have been used to operate this Ford 7000 tractor. The results are shown in Figure 2.

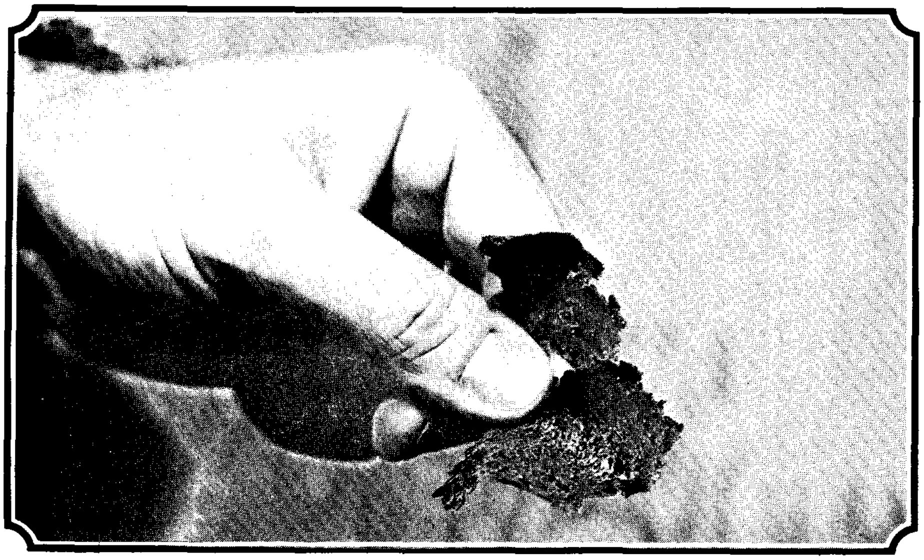
This screw expeller will squeeze about 3½ gallons of oil from 95 lbs. of sunflower seed in one hour.



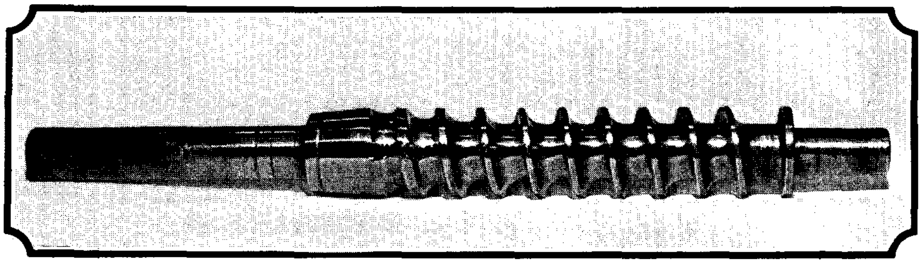
Oil must be filtered to remove seed particles over 5 microns in size. This is needed to avoid plugging of the tractor fuel filters.



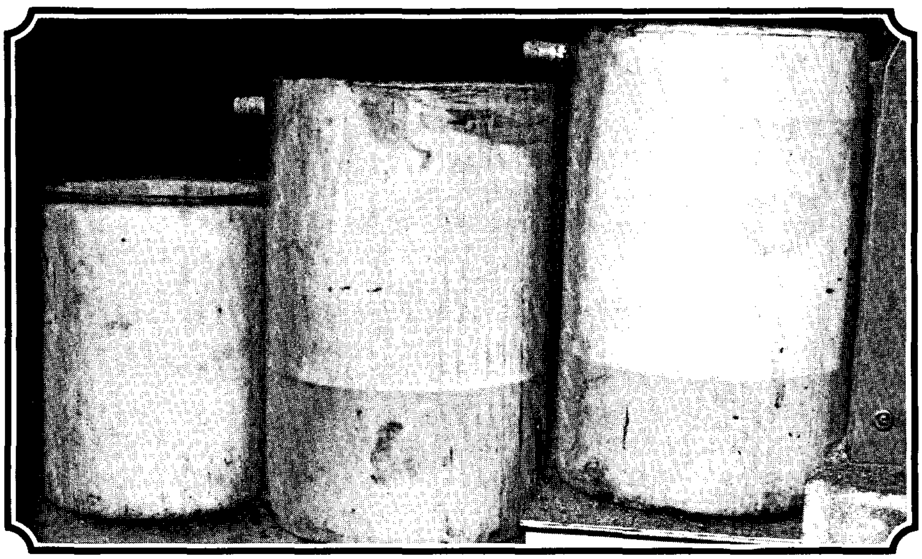
Most of the seed particles in the oil settles out after a few days as shown in the center sample. The sample on the right is filtered.



The sunflower oil meal comes out of the expeller in thin sheets that are dry. This meal may turn rancid in storage due to some residual oil remaining.



The screw expeller contains this spiral as its main working part. As the seed feeds into the unit, the oil is squeezed out directly ahead of the meal outlet. The tapered section at the outlet allows for adjustment of pressure on the seed.



Settling tanks help remove seed particles from the oil. The oil is held in these tanks several hours before it is run through the filter.