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Economic Feasibility of Diesel Fuel Substitutes from Oilseeds in New York State

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ABSTRACT

Critical factors in the economic feasibility of vegetable oils as an energy source are production, processing and transportation costs and the value of meal byproducts. This paper analyzes the economics of producing and processing vegetable oils for use as agricultural fuels in New York State, which is outside the major oilseed producing areas of the United States. Budgeting is used to estimate production costs. These are compared to existing fuels.

Technical considerations in vegetable oil use as diesel fuel and refining alternatives are discussed. Carbon buildup occurs in the engine with long-term use. Redesign of injectors, lowering of viscosity or esterification are possible solutions to the problem.

If oilseed production were expanded sufficiently to replace on-farm diesel fuel use, the impact on agriculture would be substantial. Roughly 21 percent of total New York cropland would be required to produce sufficient oil from soybeans. Sunflowers produce more oil per hectare with current yields. If sunflowers were grown instead of soybeans, eight percent of New York cropland would be required.

Current vegetable oil prices are above that of the diesel fuel they would replace. Crude soy oil sold for $0.36-0.42 per liter in 1981, compared with $0.32 per liter for diesel fuel. The price of diesel fuel must rise or prices of vegetable oils must fall below current levels for farmers to make a shift to vegetable oils.

Enterprise budgets were developed for soybeans, sunflowers and flax grown on a "typical" New York dairy farm, using 1981 prices. Processing and transportation costs were adapted from published sources. The value of the high-protein meals produced in processing was estimated based on their value as feed for dairy cows. Large-scale (900 tonnes/day) and small-scale (4.5 tonnes/day) processing plants were considered.

For all three oilseeds and both plant sizes, the cost of producing the oil is above the 1981 diesel fuel price. Soybean and flaxseed oil processed in a large-scale plant have total production, processing and transportation costs net of meal value of $0.51 and $0.46 per liter, respectively. Sunflower oil costs slightly more at $0.63 per liter. Sunflower oil processed in the small-scale plant costs $0.65 per liter.

Vegetable oils are not likely to be an economically attractive substitute for diesel fuel in New York State if the diesel fuel supply and price remains stable. Vegetable oils in the Midwestern U.S. are being produced and sold at market prices about 25 percent lower than the lowest-cost oil produced in New York State. Vegetable oil use would be expected to occur first in the Midwest.

Economic Feasibility of Diesel Fuel Substitutes from Oilseeds in New York State

Introduction

In recent years, research has focused on a number of alternative energy sources that could help reduce dependence on non-renewable hydrocarbon fuels. One alternative energy source that has shown promise of technical feasibility is that of vegetable oils for use as diesel fuel substitutes or extenders. Critical factors in the economic feasibility of this energy source are production costs for the oilseeds, processing costs for obtaining the oil, transportation costs from the production area to processing and then on to the point of use, and the value of meal byproducts.

Location of oilseed production areas and processing facilities along with processing facility size must be addressed in determining economic feasibility. Production and processing in the United States are now concentrated mainly in the Midwestern region. New York is a major agricultural state, ranking third among U.S. states in milk production and in the top five states in the production of many fruits and vegetables. Oilseed production is increasing in New York State and other Northeastern states, but further expansion is hampered by a lack of processing facilities.

Oilseed meals, mainly soybean oil meal, are currently shipped into New York State as a protein supplement for dairy cattle and other livestock. An oilseed processing plant located in New York State would avoid some of the transportation costs now incurred in shipping from points further away. Oilseed yields in New York State are currently below average U.S. levels, because of a shorter growing season, but are improving as new shorter-season varieties become available. Production costs per acre in New York are believed comparable to average U.S. levels. Lower yields with comparable costs result in higher production costs per unit. If production is widely scattered or if some oilseeds must be shipped in from other processing areas to operate processing plants at capacity, transportation costs to the processing facility would be higher than where production was concentrated near the processor. Transportation costs will increase with the size of the processing facility if the seeds must be shipped longer distances to keep the facility operating at capacity. The higher transportation costs must be weighed against lower processing costs resulting from economies of size.

The purpose of this paper is to analyze the economics of producing and processing vegetable oils in New York State for use as agricultural fuels. Technical considerations in vegetable oil use as fuel are discussed first, with some possible refining alternatives for solving the problem of shortened engine life. The utilization of existing oilseed production and requirements for increased production for fuel use are discussed. A set of enterprise budgets for soybeans, sunflowers and flax for New York conditions is presented next. Economies of scale in on-farm and large-scale plants are considered, with cost estimates taken from studies in North Dakota. Net costs per liter of vegetable oil are then calculated and compared with diesel fuel prices.

Use of Vegetable Oil as Diesel Fuel

Vegetable oil is a high-molecular-weight carbohydrate produced by plants for long-term storage of energy (Bailey, 1979). Each molecule has the structure of a triglyceride: three straight-chain fatty acids each linked to one OH group of a glycerol molecule. A fatty acid branch usually has 16 to 18 carbon atoms, and interacts with branches of other molecules to give a high viscosity and solidification temperature to the oil. The energy content of vegetable oils is high; about 37 MJ of heat are released for each liter burned (Quick, 1980).

The combustion properties of vegetable oil happen to coincide closely to those of diesel fuel. In a diesel engine, intake air is compressed in order to raise its temperature; the fuel is then injected and ignites at the increased temperature (Obert, 1973). Diesel fuel has the property of igniting at the temperatures created by compression, while gasoline tends only to ignite at the very high temperatures created by an electrical spark. One measure of the compression-ignition properties of a fuel is cetane number, which rates the performance of a fuel in a diesel engine relative to two reference fuels, one of which is cetane. Diesel fuel has a cetane number of 44 to 51, while the cetane number of vegetable oils is comparable, between 33 and 42 (U.S.D.O.E., 1980). Gasoline has a cetane number of about 17.

Vegetable oils were used for diesel fuel as far back as 1900 by Rudolf Diesel, the inventor of that engine (Nitscke and Wilson, 1965). Interest in the oils as alternative fuels has arisen since then during periods of fuel shortage (Walton, 1938; Chang and Wan, 1947). Recently, vegetable oils have received new attention by workers in Australia (Quick, 1980), South Africa (Bruwer, et al., 1980), and the United States (Goodier et al., 1980; Hofman et al., 1981). These and numerous other workers have demonstrated that almost any diesel engine can operate for at least a short time on mixtures of up to 100 percent vegetable oil (with diesel fuel) with satisfactory performance. Typically, about a 9 percent reduction in power, torque, and fuel efficiency is observed, corresponding to about a 9 percent lower energy content relative to diesel fuel. Results have been similar for all oils tested (Quick, 1980; Goering et al., 1981).

With long-term use of vegetable oils as diesel fuel, problems occur with carbon buildup in the combustion chamber, especially around the injector nozzle (Quick, 1980; Bruwer et al., 1980; Fort et al., 1982; Schinstock and Bashford, 1982). This carbonization is linked with incomplete combustion of the fuel. The unburned fuel slowly leaks past the piston rings into the lubricating oil, and if this contamination continues unchecked, the lubricating oil will congeal and cause complete engine breakdown. Such problems usually occur within 1000 hours of operation in "direct-injection" engines, in which the fuel is sprayed directly into a main combustion chamber. In "indirect-injection" engines, the fuel is injected into an adjoining pre-combustion chamber, and the flame then spreads to the main chamber. A tractor engine of this type has been operated without difficulty for 2300 hours on pure sunflower oil (duPlessis, 1981). However, most American tractor engines are the direct-injection type.

Part of the reason for carbonization with vegetable oils is the presence of gums (phosphatides) in the oils. The gum content varies among different crops: sunflower seed oil contains only 0.5 percent gum, while soybean oil contains up to 3.2 percent (Bailey, 1979). In engine tests performed by the authors with a Ford 4000 3-cylinder engine and dynamometer, it was found that engine startup and operation were impossible with crude sunflower oil, but after the oil was degummed, the engine performed without difficulty for short-term tests.

Removal of gums from crude vegetable oil is a simple process. The gums absorb water, becoming heavier than the surrounding oil and settling out. Experiments performed by the authors using the ASTM Standard Method show that degumming is adequately accomplished by adding 2 percent water (by volume), agitating gently for 1/2 hour, and settling for 4 to 5 days.

Carbonization in the engine still occurs in long-term operation with degummed oil. The reason for this is widely believed to be the oil's high viscosity, about 10 times that of diesel fuel. Nozzle injectors are designed to atomize diesel fuel into a fine spray that achieves good contact between oxygen and fuel in the combustion chamber. With vegetable oil, the spray droplet size is much larger, and thus less of the oil comes in contact with oxygen and combusts. One solution to this problem might be to redesign the nozzle injectors, but as yet such redesign has not been undertaken. Another partial remedy is to mix the oil with diesel fuel to reduce the overall viscosity; however, the viscosity of the mixture approaches that of diesel fuel only if a high fraction of diesel fuel is used. A third possibility is to lower the viscosity by preheating the oil before it reaches the nozzle injectors, although the required temperature of preheating has never been determined.

Another possibility for reducing the oil's viscosity is esterification of the oil by chemical reaction with alcohol. This reaction involves replacing the glycerol part of the oil molecule with alcohol. The main product, esters, has viscosity comparable to that of diesel fuel at room temperature. Bruwer et al. (1980) and others have found that esters burned in an engine give less carbonization and greater thermal efficiency than diesel fuel itself. However, the esters may cause the injector needles to stick, and they crystallize at about 5°C. Experiments by the authors on producing esters showed that 24 and 37 percent anhydrous methyl or ethyl alcohol, respectively, is needed in combination with a catalyst at 65°C. Hydrated (190 proof) alcohol may also be used, but centrifuging may then be necessary to separate the esters from the other products.

Another possibility for reducing the oil's viscosity is to mix the oil with solvents such as butanol, acetone (Goering et al., 1981), or kerosene. Of these, kerosene is the most promising due to its current availability, its low viscosity about half that of diesel fuel), and its adequate compression-ignition properties (cetane number 45 to 50). Kerosene is an organic solvent and therefore mixes permanently with vegetable oil. Mixtures of 25, 50, and 75 percent kerosene have viscosities about 1/3, 1/5, and 1/10 that of vegetable oil, respectively. Short-term engine tests performed by the authors with a mixture of 25 percent kerosene, 75 percent sunflower seed oil show that performance is slightly improved over pure oil. However, long-term engine tests have not yet been performed.

It is likely that with the research effort underway worldwide on the use of vegetable oils as fuel, the technical problems associated with it will be solved in the near future. Thus, important consideration in the adoption of vegetable oil as fuel will probably be the economics and profitability of producing it.

Utilization of Existing Oilseed Production

The vast majority of oilseed production worldwide is utilized as processed oils and high protein meal. Oilseed markets in the U.S. are closely tied to world markets, with 51 percent of soybeans and meal exported in 1980 (Agricultural Outlook).

For a given oilseed, oils and meal are joint products produced simultaneously in fixed proportions during processing. While closely linked in production, the market demands for oils and meals are largely independent of one another and influenced by quite different economic forces.

Up to 1967 the demand for oilseed meals had grown more rapidly than oil demand, stimulating a shift toward oilseeds and nuts as the most important source of fats and oils. Meanwhile marine, animal and palm products have declined in relative importance. With a higher yield of meal than other oilseeds, soybeans have emerged as the world's leading oilseed commodity. The average percentage yield of oil and meal by weight for the major oilseeds is shown in Table 1.

Table 1. Average Percentage Yield by Weight for Major Oilseeds

Oilseed	Meal	Oil
Soybean	80	17
Sunflower	68	31
Flax	64	35
Peanut	58	42
Rapeseed	58	40
Palm-kernel	52	46
Cottonseed	46	18
Copra	35	64

Source: Houck, Ryan and Subotnik.

The increasing demand for meal has led to an increase in meal price relative to oil. For example, Houck et al. (1972) state that before 1957, meal and oil interchanged as the most valuable component of soybeans because of varying relative prices. The relative value of meal has increased until 1979, in which meal amounted to 72 percent of the value of soybeans at U.S. average wholesale prices (Table 2).

Table 2. Relative Value of Soybean Oil and Meal, 1960-79, U.S. Average Prices

Year	44% Protein Meal		Crude Soy Oil		Total Processed Value ($/t.)	Meal Value	Oil Value
	Price ($/t. meal)	Value in 1 Tonne of Soybeans (dollars)	Price ($/t. oil)	Value in 1 Tonne of Soybeans (dollars)		(Percent of Total Processed Value)	
1960	89.07	71.21	249.12	42.33	113.54	63	37
1965	108.69	86.86	260.14	44.31	131.17	66	34
1970	123.90	99.21	282.19	48.06	147.27	67	33
1975	196.21	156.97	403.44	68.56	225.53	70	30
1979	287.26	229.72	535.71	91.05	320.77	72	28

Source: USDA, Fats and Oils Situation

This shift in relative value in favor of meal does not in itself suggest that the use of vegetable oil as a fuel substitute will be economically feasible in the near future. However, it does suggest that if oilseed production continues to increase to meet an increasing demand for meal, oil prices may fall to a point where they become competitive with other liquid fuels.

Oilseed Production Required to Replace Diesel Fuel for On-Farm Use

In 1978, 12.5 billion liters of diesel fuel were consumed on U.S. farms. Of this total, 150 million liters were consumed in New York State (Census of Agriculture). Production of vegetable and industrial oils in the U.S. in 1979/80, shown in Table 3, was about 13 million tonnes.[1] Since vegetable oils consistently weigh about 0.92 kg per liter, total production was 13.8 billion liters of oil. This indicates that U.S. vegetable and industrial oil would approximately have to double to replace total current agricultural diesel fuel use, assuming that vegetable oil substitutes for diesel fuel on the basis of heating value, which is about 90 percent that of diesel fuel.

Table 3. U.S. Production of Vegetable and Industrial Oils, 1979/80[a], (1,000 tonnes)

Type of Oil	Production
Vegetable Oils	
Soybeans	10,269
Cottonseed	625
Peanut	170
Sunflowerseed	1,185
Safflowerseed	63
Corn	350
Industrial Oil	
Linseed (Flax)	102
Total	12,764

$$12{,}764{,}000 \text{ tonne} \times \frac{1000 \text{ kg}}{1 \text{ tonne}} \times \frac{1 \text{ liter}}{0.92 \text{ kg}} = 13.8 \times 10^9 \text{ liters}$$

[a]Preliminary data for 1979/80. Oil production calculated from assumed extraction rates applied to that portion of each crop available for crushing and/or export (not actual production).

Source: E. H. Pryde. "Vegetable Oil vs. Diesel Fuel: Chemistry and Availability of Vegetable Oils." in Alcohol and Vegetable Oil as Alternative Fuels. Proceedings of Regional Workshops, Peoria, Illinois, April 28-30, 1981.

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[1]Linseed oil from flax is classified by Pryde (1981) as an industrial oil, but is termed a vegetable oil for the purposes of this study.

If oilseed production were expanded sufficiently to replace on-farm diesel fuel use, the impact on the agricultural sector would be substantial. Table 4 gives the land area necessary for selected oilseeds and gives a comparison with existing cropland utilization. If the expanded oilseed cropland were put into soybeans, this required land area would then be 21 percent of total cropland. However, use of vegetable oil for fuel might shift production to oilseeds with higher oil content, such as sunflowers. If the expanded oilseed cropland were put into sunflowers, then 12 percent of total cropland would be required.

Table 4. On-Farm Fuel Requirements in the United States

Item	Amount
On-farm diesel fuel consumption, 1978	12.5×10^9 liters
Vegetable oil required to substitute[a]	13.8×10^9 liters
Hectares required to substitute (average oil yields[b]), millions	
Soybeans (190 liters per hectare)	40
Sunflowers (350 liters per hectare)	22
Peanuts (850 liters per hectare)	16
Cotton (150 liters per hectare)	92
1978 United States land utilization, million hectares	
Harvested crops	130
Cropland used only for pasture or grazing	31
Other cropland	26
Total cropland	187
Pasture and rangeland other than cropland and woodland pasture	177

[a]Assumes that vegetable oil has 90 percent of the heat content of diesel fuel.

[b]Average oil yields are based on 1970-74 U.S. averages, except for sunflower oil yields which are based on 1977-78 data. Assumes 0.92 kg of oil per liter. Source: Adapted from Pryde (see previous table).

The oilseed crops that could potentially be grown most widely in New York State appear to be soybeans, sunflowers and flax. Soybeans and sunflowers are currently grown on limited acreages in New York State for non-fuel use. Soybean acreage averaged 8,400 hectares in New York for the five-year period 1976-80, while sunflower cropland in 1978 was 700 hectares (Census of Agriculture, N.Y. Agricultural Statistics). It appears that most soybean production currently moves to the Atlantic Coast for export, while sunflower production is utilized principally for birdseed and for human consumption. No flax is currently grown in New York, although it is grown on marginal soils in eastern Canada and therefore is worth considering. The climate in New York State is too cold for cottonseeds and appears to be too humid for successful safflowerseed production. Only very limited areas exist of soils sandy enough for peanuts. These are used intensively for potato and vegetable production. Soybeans, sunflowers and flax can all be grown with technology similar to that presently used by New York dairy and field crop farmers for forage and grain production. Hence we will focus on these three crops as potential alternatives.

Soybean yields averaged about 25 60-pound bushels per acre or 1.68 tonnes per hectare in New York State over the five-year period 1976-80, somewhat below those of the major soybean producing areas in the Midwest (N.Y. Agricultural Statistics). However, a 1979 study of growers in central New York found yields averaging 30 bushels per acre (Anderson and Snyder, 1980). Recent development of higher-yield early varieties adapted to New York may lead to higher farm yields in the future. Extractible oil content is fairly constant at about 17 percent by weight.

Sunflower yields in New York in 1978 equalled the soybean yield, 1.68 tonnes per acre (Census of Agriculture). Sunflower varieties consist both of oil types grown primarily for oil extraction, and of non-oil types grown primarily for human consumption. Oil yields per hectare for the two types are roughly comparable under New York conditions, with non-oil varieties having a higher proportion of hulls. Both oil and non-oil varieties are grown in New York State. Oil content also varies with temperatures during growth, decreasing as temperatures rise. Oil varieties of sunflower seed typically yield 45 percent oil in New York variety trials. Yield losses to birds can be severe, with losses of 48 percent in one trial location and 79 percent in another location in 1981 (Wright, 1982). Diseases can also be a problem, limiting sunflowers to a rotation of roughly one year out of six in a given field.

Based on yields in other areas of the U.S. and Canada, the best estimate of flax yields in New York State is 1.35 tonnes per hectare with an oil content of 40 percent. Because of its shallow root system, flax does not compete well with weeds.

From Table 5, it can be seen that roughly 21 percent of total New York cropland would be required to produce sufficient oil from soybeans to substitute for the diesel fuel currently used on New York farms. For sunflowers and flax, the figures are 8 and 11 percent, respectively.

Recent Trends in Prices of Diesel Fuels and Vegetable Oils

Current vegetable oil prices are above that of the diesel fuel they would replace. In the absence of outright diesel fuel shortages, the price of diesel fuel must rise or prices of vegetable oils must fall below current levels for farmers to make a shift to vegetable oils. Most oilseed processing facilities are located in the Midwest and Northern Plains states, so that oil prices are likely to be lowest in those areas and increase by a transportation differential in other areas. Table 6 shows season average prices for crude soybean and sunflower prices f.o.b. Decatur and, for comparison, diesel fuel prices paid by farmers in Illinois. The cost of any further refining necessary for satisfactory engine performance and the cost of transportation to the farm would add to the cost of using vegetable oils as fuels.

Table 5. On-Farm Fuel Requirements in New York State

Item	Amount
On-farm diesel fuel consumption, 1978	149×10^6 liters
Vegetable oil required to substitute[a]	165×10^6 liters
Hectares required (average oil yields,[b]), thousands	
Soybeans (310 liters per hectare)	536
Sunflowers (805 liters per hectare)	206
Flax (580 liters per hectare)	285
1978 New York land utilization, thousand hectares	
Harvested crops	1,814
Cropland used only for pasture or grazing	483
Other cropland	203
Total cropland	2,500
Pasture and rangeland other than cropland and woodland pasture	341

[a]Assumes that vegetable oil has 90 percent of the heat content of diesel fuel.

[b]Soybean seed yields are averages for 1976-80. Sunflower yields are for 1978. Flax seed yields are estimated from those obtained in other parts of the U.S. and Canada. Oil percentage yields are assumed to be 17 percent for soybeans, 45 percent for sunflowers and 40 percent for flax (from Madison Wright).

Vegetable oil prices are still above diesel fuel prices at 1981 levels, although the spread is narrowing. Diesel fuel prices have increased at an arithmetic average of 8.4 cents per year for 1970 through 1982. Crude soy oil prices increased at 5.4 cents per year over this period, although they have fluctuated wildly. Projecting these rates from 1981 prices gives equality of the two prices by about 1990.

No oilseed processing facility currently exists in New York State. The closest existing facilities are in western Ohio and Delaware (American Soybean Association, 1981). Therefore, the costs of building and operating a processing facility were considered. Cost estimates from studies for North Dakota were taken as a starting point, and adjusted to 1981 price levels using USDA indices of prices paid by farmers. A more detailed cost analysis would be needed before such a facility was constructed, but it is hoped that the present analysis gives an indication of whether and under what conditions a further analysis would be warranted. To indicate the extent of the economies of scale involved and to give a comparison with current industry operating margins, two sizes of facilities are considered:

Table 6. Recent Vegetable Oil and Diesel Fuel Prices

Year	Crude Soy Oil, Decatur	Crude Sun Oil, Decatur	Diesel Fuel
	($/1)[a]	($/1)[a]	($/1)
1970	0.26	--	0.05
1971	0.24	--	0.05
1972	0.31	--	0.06
1973	0.62	--	0.07
1974	0.65	--	0.10
1975	0.38	--	0.10
1976	0.49	--	0.11
1977	0.50	--	0.13
1978	0.55	0.67	0.13
1979	0.49	0.53	0.19
1980	0.46	0.55	0.27
1981	0.36-0.42	0.51	0.32

[a]Assumes 0.92 kg per liter.

1) an industrial facility processing 900 tonnes of seed/day, and
2) a small, on-farm facility, processing roughly 4.5 tonnes of seed/day.

Oilseed Enterprise Budgets

A set of enterprise budgets was developed to estimate the cost of producing oilseeds in a "typical" dairy farm situation in New York State. Budgets were developed for the three crops thought to have the greatest potential for oil production in New York State: soybeans, sunflowers, and flax. The budgets are not intended to represent any particular farm and are not averages for any group of farms but do exhibit the economics for a given set of conditions. State average soybean yields for 1979 and 1980 and average sunflower yields for 1978 are used. Flaxseed yields were based on results in Minnesota and Ontario. Seed, fertility and pesticide requirements to achieve these yields were developed in cooperation with Madison Wright of the Department of Agronomy at Cornell University.

The budgets are constructed using the economic engineering approach. Prices and costs which existed in 1981 are related to a specified land base and corresponding building and machinery complement. The land base consists of 200 tillable hectares, with 40 hectares of one of the oilseed crops together with 40 hectares each of a hay crop, corn silage, corn grain, and a row cash crop. The machinery complement for the oilseed is chosen to be consistent with this crop mix. The reason for specifying all crops grown is that the proportion of the machinery investment cost is charged to the oilseed crop based on annual hours use on that crop as a proportion of total use on all crops. The economic-engineering approach used for calculating machinery costs is that described in Sprague et al. (1980).

The assumed machinery complements are shown in Table 7. Machinery is assumed to have a nine-year life, purchased in equal proportions in each of the past nine years. Thus, 1981 machinery purchase prices are converted to an average of prices over the past nine years using a price factor which is the average of indices of prices paid by U.S. farmers for 1973 through 1981, divided by the index of prices paid in 1981. A share of machinery costs is allocated to the oilseed crops on the basis of hours of use on these and other crops. The machinery complements for soybeans, sunflowers and flax are alike with one exception: a corn planter is used for planting sunflowers, while a drill is used for soybeans and flax.

The enterprise budgets are shown on a per acre basis in Table 8. A management charge equal to 10 percent of the variable and fixed costs other than land is included. Labor hours are calculated as 1.2 times machine hours. Quantities of seed, fertilizer, lime and labor are shown in parentheses for each crop. The oilseed enterprise budgets show that soybeans have the lowest total cost per tonne at $309. Sunflowers and flax cost $345 and $318 per tonne, respectively.

Processing Costs - Large-Scale vs. On-Farm

The current soybean processing industry includes a range of plant sizes from small screw expeller plants of 25-35 tonnes of beans per day to huge solvent extraction plants which can handle up to 1,500 tonnes per day. The trend is toward the larger solvent plants which are more efficient in oil recovery and better suited to automated storage and loading facilities than capable of processing flaxseed at 1,300 tonnes per day and soybeans at 1,100 tonnes per day. These cost figures updated to 1981 price levels give a rough indication of the current cost of building and operating such a plant in New York State, although locational price differences are not included.

The variable and fixed costs from Helgeson et al. are itemized in Table 9. The index factor used for adjusting prices to 1981 levels is the ratio

$$\frac{\text{index of prices paid in 1981}}{\text{index of prices paid in 1975}}$$

applied to each category of cost item as reported in the U.S. Department of Labor's *Monthly Labor Review*.

Processing costs for a large-scale plant, after adjusting to 1981 prices, are summarized in Table 10. Annual ownership and operating costs are the same for all three oilseeds. However, capacity varies, giving different costs per tonne of seed. Sunflower is the most expensive at $30.90 per tonne, $24.70 for soybeans and $22.00 for flax.

Table 7. Machinery Complements and Investment Costs for Soybeans, Sunflowers and Flax

	1981 Cost	Price Factor	Investment Cost	Proportion Charged to Oilseeds	Soybeans	Sunflowers	Flax
					Proportional Cost		
Tractor (90 kw with cab)	50,000	.576	$ 28,800	.15	$ 4,320	$ 4,320	$ 4,320
Tractor (45 kw)	18,000	.576	10,368	.20	2,074	2,074	2,074
Plow 5-45 cm bottoms	9,000	.687	6,183	.24	1,484	1,484	1,484
Disk Harrow (5 m)	7,400	.687	5,084	.24	1,220	1,220	1,220
Spring Tooth Harrow (5 m)	2,100	.687	1,443	.24	346	346	346
Corn Planter (4 row)	7,000	.687	4,809	.33		1,587	
Drill (3 m)	5,100	.687	3,504	.80	2,803		2,803
Sprayer (9 m)	3,200	.687	2,198	.20	440	440	440
Combine w/4 m grain head	55,000	.576	31,680	.33	10,454	10,454	10,454
Wagons 2 @ $2,500	5,000	.687	3,435	.33	1,134	1,134	1,134
Pickup Truck	7,500	.865	6,488	.20	1,298	1,298	1,298
Total Investment			$108,870		$25,573	$27,160	$25,573

Table 8. Enterprise Budgets for Soybeans, Sunflowers and Flax

	Soybeans		Sunflowers		Flax	
VARIABLE EXPENSES:						
Growing						
Seed, (kg)	(67)	$35.58	(7)	$19.57	(45)	$14.41
Fertilizer:						
N (kg)	(11)	7.91	(67)	47.49	(28)	19.77
P (kg)	(34)	20.76	(22)	13.84	(17)	10.38
K (kg)	(45)	15.76	(22)	7.88	(6)	1.98
Lime (t)	(.56)	17.30	(.56)	17.30	(0)	0
Herbicide[a]		19.64		36.20		4.94
Machinery:						
Fuel, Oil, Grease		21.37		21.60		21.60
Repairs & Maintenance		7.73		6.94		7.73
Other		6.67		6.67		0
Total Growing Expenses		$152.72		$177.49		$80.81
Harvesting						
Machinery:						
Fuel, Oil, Grease		8.72		8.75		8.75
Repairs & Maintenance		5.39		5.43		5.86
Drying		0		4.42		0
Other		6.55		6.55		1.19
Total Harvesting Expenses		$20.68		$25.15		$15.80
Interest on Operating Expenses[b]		13.74		17.99		5.73
Family & Hired Labor (hr.)	(5.2)	24.44	(5.2)	24.78	(5.9)	28.22
Total Variable Expenses		$211.56		$245.41		$130.56
FIXED EXPENSES:						
Machinery[c]		137.68		131.23		137.68
Dryer[c]		0		29.11		0
Machine Storage[d]		9.49		9.04		9.49
Land Charge		123.55		123.55		123.55
Management Charge		36.20		41.19		27.82
Total Fixed Expenses		$306.92		$334.12		$298.54
TOTAL EXPENSES, PER HECTARE		$518.48		$579.53		$429.10
Yield per hectare, tonne		1.68		1.68		1.35
TOTAL EXPENSES, PER TONNE		$308.62		$344.96		$317.85

[a]Herbicides include 1.75 l. of Treflan per hectare on soybeans, and 1.75 l. Treflan, 1.2 l. Paraquat defoliant and 0.15 l. surfactant on sunflowers. No herbicides are included for flax.

[b]Interest on operating expenses charged at an annual rate of 15 percent for 6 months.

[c]Interest at 15 percent and insurance at 0.5 percent charged on average investment, plus straight line depreciation over 9 years with 10 percent salvage value.

[d]Machine storage charged at 1.5 percent of average investment per year.

Table 9. Estimated Costs per Year for a Large-Scale Processing Plant

	1975 Cost	Index Factor	1981 Cost	Price Index Used
VARIABLE EXPENSES				
Fuel	$ 483,000	3.13	$1,511,462	a
Solvent	83,160	1.76	1,462,223	b
Wages	424,000	1.60	679,280	c
Social Insurance Expenses	135,680	1.37	185,769	d
Electricity	650,160	1.90	1,233,085	e
Water	15,600	1.90	29,587	e
Repairs and Maintenance	348,890	1.63	568,730	f
Interest on Seasonal Capital	883,730	1.95	1,941,662	d,g
Insurance on Inventory	62,380	1.55	96,689	d
Product Selling Expense	78,000	1.60	124,962	c
Inventory Losses	207,940	1.37	284,697	d
Total Variable Expenses	$3,372,540		$6,802,141	
FIXED EXPENSES				
Depreciation	231,630	1.63	377,583	f
Interest on Capital	293,250	2.66	767,122	g
Salaries	63,000	1.60	100,931	c
Administrative	117,300	1.60	187,924	c
Insurance (Plant)	24,350	1.63	39,693	f
Property Taxes	82,800	1.43	118,025	f
Building Maintenance	19,900	1.63	32,439	f
Total Fixed Expenses	$ 832,230		$1,623,717	
TOTAL EXPENSES PER YEAR	$4,204,770		$8,425,858	

Source: All indices are from the USDL, Monthly Labor Review unless unless otherwise indicated.

Price Indices Used:

a. Petroleum products, refined.
b. Industrial Chemicals.
c. Adjusted gross hourly earnings, manufacturing.
d. Hay, hayseeds and oilseeds
e. Electric power.
f. Machinery and equipment.
g. Corporate Bond Yields, Economic Report of the President.

Transportation would be necessary for seed moving from farms to a large-scale plant and for the processed oil and meal moving back to the farms. Average transportation costs would be much lower than for oilseed production concentrated in a small area than for widely dispersed production such as presently exists in New York. If oilseed production and processing for fuel became profitable, oilseed production would doubtless

Table 10. Summary of Processing Costs, Large Scale Plant, 1981 Prices

Item	Soybeans	Sunflowers	Flax
Annual ownership and operating costs	$8,425,858	$8,425,858	$8,425,858
Capacity, t/yr.	330,000	270,000	390,000
Cost/tonne of seed	$24.70	$30.90	$22.00
Oil yield, percent of seed weight	17.0	44.6	39.6
Cost/liter of oil @ 0.92 kg/l	$0.13	$0.06	$0.05

intensify considerably near the plant. It is beyond the scope of this study to predict the amount and location of acreage that might develop in New York State.

Transportation costs are estimated for an arbitrary average of 240 km from farm to plant. A grain terminal in Central New York reported a typical trucking charge of 13.20 per m^3, or $14.78 per tonne for soybeans hauled that distance. That price per m^3 is used in the study for all seeds and meals. Kalter et al. (1980) reported a price of $18.30 per tonne for trucking fuel alcohol the same distance. That price is used as an oil transportation cost.

On-Farm Processing Costs

The economics of on-farm processing have also been extensively studied in North Dakota. Helgeson and Schaffner estimated costs for three sizes of on-farm sunflower processing units with capacities of 0.32, 1.52, and 4.5 tonnes per nine-hour day (Table 11). Percentages of oil extracted were 82 percent for the smaller unit and 89 percent for the two larger units, compared to 99 percent for the large scale plant described above.

It should be noted that the costs for the large-scale plants include a number of items not included for the small-scale ones, so the two figures are not directly comparable. Notably, interest on seasonal capital, insurance on inventory, and inventory losses are expenses which a New York farmer would likely incur but are not included in Table 10. These account for $8.60 of the total processing cost per tonne. These on-farm costs assume operation for 300 days per year, similar to the large-scale plants. Costs would rise if the plants are operated less intensively.

Table 11. Estimated Costs for Processing 300 Nine-Hour Days by Three Sizes of Presses

Cost Item	0.32 Tonnes Per Day	1.52 Tonnes Per Day	4.5 Tonnes Per Day
Variable Costs			
Equipment Repair[a]	$ 2,990	$ 3,601	$ 5,507
Building Repair[b]	225	225	262
Electricity @ $0.40/ kilowatt hr.[c]	165	822	2,446
Hired Labor @ $5.00/hr.	6,300	12,100	13,030
Total Variable Cost	$ 9,680	$16,748	$21,245
Fixed Costs			
Equipment Amortized for 15 Years[d]	2,289	2,640	3,676
Building Amortized for 25 Years[e]	1,229	1,229	1,431
Insurance on Building and Equipment[f]	174	190	249
Management, Owner Operator Labor @ $5.00/Hour	7,200	1,400	470
Total Fixed Cost	10,892	5,459	5,826
Total Processing Cost	$20,572	$22,207	$27,071
Total Tonne of Sun Seeds Processed	95	450	1,360
Processing Cost Per Tonne of Sun Seeds	$216.55	$49.35	$19.90
Processing Efficiency[g]	82%	89%	89%

Source: Adapted from Helgeson and Schaffner.

[a]The annual equipment repair costs were charged on a percentage basis of new cost as follows: press 27%, filter 21%, other equipment 4%.

[b]Steel building repair charged at 2% of new cost.

[c]1981 commercial utility rate.

[d]Depreciation and interest on equipment were amortized over 15 years at 10% interest paid quarterly. The 10% interest was the average paid for Baa industrial bonds for 1975-79.

[e]Depreciation and interest on the building were amortized over 25 years at 10% interest paid quarterly.

[f]$6.00/$1,000 charged on equipment and building.

[g]Percent of oil removed.

We chose the 4.5 tonne per day plant for our on-farm processing cost comparison. Adding the $8.60 for interest, insurance and losses to the $19.90 from Table 11 gives a total processing cost of $28.50 per tonne.

The 4.5 tonne per day plant would probably provide more oil and meal than could be consumed on a single farm if operated 300 days per year, but would not require transportation over long distances as with the large scale unit. To evaluate the feasibility of an on-farm plant, the transportation cost was reduced by one-half to $6.60 per m^3 seed and $9.15 per tonne of oil.

Meal Value

Soybean meal prices paid by New York dairy farmers averaged $335 per tonne in 1981. Sunflower and flaxseed meals are not currently used by New York farmers in any significant quantities, so market prices are not available. A simultaneous equation technique developed by Wayne Knoblauch of the Department of Agricultural Economics at Cornell University was used to solve for prices of crude protein and energy in any feed based on soybean oil meal and corn grain prices. Using a corn price of $106 per m^3 ($3.21 per bushel), this gives 60 cents per kg of crude protein and 1 cent per MJ of energy. These prices are used together with estimates of protein and energy content from Milligan et al. (1981) to estimate meal values of $327.66 and $298.56 per tonne, respectively, for sunflowers and flaxseed. These prices are used to calculate a credit for the meal value which is subtracted from the production, processing and transportation costs to get a net cost per liter of oil.

The meal produced in on-farm processing is not of the same quality as that from large-scale processing for two reasons: first, the oil content is higher due to an extraction rate of 89 compared to 99 percent, and second the hulls are not removed and so increase the fiber content. However, there is little data available on the actual difference in feeding value, so the same prices were used for protein and energy. No value was placed on the added oil or hulls.

Net Cost of Processed Oil

Tables 12 through 15 show the cost of producing oil for each of three selected oilseeds. In all cases, the oil cost is above the 1981 diesel fuel price and the market prices for vegetable oils. Soybean and flaxseed oil processed in a large-scale (900 tonnes per day) plant have essentially the same costs at $0.51 and $0.46 per liter (Tables 12 and 14). Sunflower oil costs slightly more at $0.63 (Table 13). All of these alternatives require substantial oilseed cropland to keep the processing plant in operation year-round. A smaller-scale alternative, a 4.5 tonnes per day sunflower plant, has a cost of $0.65 per liter, nearly identical to the large-scale costs (Table 15). Thus it would appear that the lower processing costs of the large-scale plant and the reduction in extraction rate from 99 to 89 percent are exactly offset by the effects of reducing the transportation costs by half. The one-half reduction in transportation costs is a crude estimate but is in line with current trucking rates. Accurate esti-

Table 12. Estimated Soybean Oil Cost - Large Scale Processing

		Cost
PRODUCTION		
Total production cost per hectare	\$518.48	
Yield per hectare	1.68 t	
Production cost per tonne of seed		\$308.62
PROCESSING		
Total processing cost per year	\$8,425,858	
Quantity processed per year	330,000 t	
Processing cost per tonne of seed		24.70
TRANSPORTATION		
Seed \$13.20/m^3 x 1.12 m^3/t = \$14.78/t		
Meal \$13.20/m^3 x 1.12 m^3/t x 80 percent = \$11.83/t		
Oil \$18.30/t x 17 percent = \$3.11/t		
Transportation cost per tonne of seed		29.72
TOTAL COST PER TONNE OF SEED		363.04
MEAL VALUE		
Crude protein value per tonne of meal (20 kg @ \$0.60)	261.95	
Net energy value per tonne of meal (350 MJ @ \$0.01)	73.21	
Total meal value per tonne	335.16	
Quantity of meal per tonne of seed	0.80 t	
Credit for meal value per tonne of seed		-268.13
NET COST PER TONNE OF SEED		\$94.91
OIL QUANTITY PER TONNE OF SEED at 99 percent extraction rate	170 kg	
NET COST OF OIL PER LITER, 0.92 kg/l		\$0.51

Table 13. Estimated Sunflower Oil Cost - Large Scale Processing

		Cost
PRODUCTION		
Total production cost per hectare	\$579.53	
Yield per hectare	1.68 t	
Production cost per tonne of seed		\$344.96
PROCESSING		
Total processing cost per year	\$8,425,858	
Quantity processed per year	270,000 t	
Processing cost per tonne of seed		30.90
TRANSPORTATION		
Seed \$13.20/m^3 x 2.09 m^3/t = \$27.59/t		
Meal \$13.20/m^3 x 2.09 m^3/t x 35 percent = \$9.66/t		
Oil \$18.30/t x 45 percent = \$8.24		
Transportation cost per tonne of seed		45.49
TOTAL COST PER TONNE OF SEED		\$421.35
MEAL VALUE		
Crude protein value per tonne of meal (20 kg @ \$0.60)	268.13	
Net energy value per tonne of meal (275 MJ @ \$0.01)	58.43	
Total meal value per tonne	326.56	
Quantity of meal per tonne of seed	0.35 t	
Credit for meal value per tonne of seed		-114.30
NET COST PER TONNE OF SEED		\$307.05
OIL QUANTITY PER TONNE OF SEED at 99 percent extraction rate	446 kg	
NET COST OF OIL PER LITER, 0.92 kg/l		\$0.63

Table 14. Estimated Flaxseed Oil Cost - Large Scale Processing

		Cost
PRODUCTION		
Total production cost per hectare	\$429.10	
Yield per hectare	1.35 t	
Production cost per tonne of seed		\$317.85
PROCESSING		
Total processing cost per year	\$8,425,858	
Quantity processed per year	390,000 t	
Processing cost per tonne of seed		22.00
TRANSPORTATION		
Seed \$13.20/m^3 x 1.20 m^3/t = \$15.84/t		
Meal \$13.20/m^3 x 1.20 m^3/t x 59 percent = \$9.35/t		
Oil \$18.30/t x 40 percent = \$7.32/t		
Transportation cost per tonne of seed		32.51
TOTAL COST PER TONNE OF SEED		\$372.36
MEAL VALUE		
Crude protein value per tonne of meal (18 kg @ \$0.60)	230.42	
Net energy value per tonne of meal (322 MJ @ \$0.01)	68.36	
Total meal value per tonne	298.78	
Quantity of meal per tonne of seed	0.59 t	
Credit for meal value per tonne of seed		-176.28
NET COST PER TONNE OF SEED		\$196.08
OIL QUANTITY PER TONNE OF SEED at 99 percent extraction rate	396 kg	
NET COST OF OIL PER LITER, 0.92 kg/l		\$0.46

Table 15. Estimated Sunflower Oil Cost - On-Farm Processing

		Cost
PRODUCTION		
Total production cost per hectare	$579.53	
Yield per hectare	1.68 t	
Production cost per tonne of seed		$344.96
PROCESSING		
Processing cost per tonne of seed		28.51
TRANSPORTATION		
Seed $6.60/$m^3$ x 2.09 m^3/t = $13.79/t		
Meal $6.60/$m^3$ x 2.09 m^3/t x 35 percent = $4.83/t		
Oil $9.15/t x 40 percent = $3.66/t		
Transportation cost per tonne of seed		22.28
TOTAL COST PER TONNE OF SEED		$395.75
MEAL VALUE		
Crude protein value per tonne of meal (20 kg @ $0.60)	268.13	
Net energy value per tonne of meal (275 MJ @ $0.01)	58.43	
Total meal value per tonne	326.56	
Quantity of meal per tonne of seed	0.35 t	
Credit for meal value per tonne of seed		-114.30
NET COST PER TONNE OF SEED		$281.45
OIL QUANTITY PER TONNE OF SEED at 89 percent extraction rate	400 kg	
NET COST OF OIL PER LITER, 0.92 kg/l		$0.65

mates of extraction rates and meal feeding value for the on-farm processor and soybeans and flax are not available. If extraction rates are the same as sunflowers, 89 percent, and if feeding values are the same as for large-scale processing despite the higher residual oil content, costs per liter would be $0.52 per liter for soybeans and $0.46 for flaxseed. However, more research is needed with the on-farm unit to confirm these assumptions.

Also, in the present analysis, the oil cost is calculated as a residual after subtracting meal value. A large increase in oilseed production would increase the supply of meal substantially. In the absence of further increases in demand, meal prices would fall, increasing the net cost of the oil. For example, meal value is 74 percent of total production and processing cost for soybeans. Therefore, a 10 percent drop in the meal price would increase the oil cost 28 percent.

Conversely, an increase in the yield per hectare would reduce production costs per tonne if costs per hectare were held constant. A 20 percent increase in soybean yield would reduce the oil cost 55 percent to $0.23 per liter.

Conclusions

Vegetable oils have shown promise of technical feasibility as a substitute for diesel fuel. Demand for high-protein oilseed meals is increasing relative to oil demand for food purposes, leading to a shift in the relative values of oil and meal toward higher value for the meal fraction. Vegetable oil prices have increased at a slower rate than diesel fuels. However, oil prices as of 1981 are still above diesel fuel prices. A substantial shift in land use would be required to produce enough vegetable oil for on-farm use, leading to much different price relationships from those existing in 1981.

Processing is necessary to convert oilseeds to a useful fuel. Studies from North Dakota were reviewed to develop preliminary estimates of processing costs for two sizes of processing plants. The value of the meal and a charge for transportation were subtracted to give a net cost for the oil.

The implications for the future are that vegetable oils are not likely to be an economically attractive substitute for diesel fuel in New York State and other states in the Northeastern U.S. if the diesel fuel supply and price situation remains stable. In the event of a major and prolonged reduction in diesel fuel availability, limited substitution of vegetable oils may occur. Vegetable oils in the major producing areas of the Midwestern U.S. are being produced and sold at market prices about 25 percent lower than the estimated cost for the lowest cost produced in New York State. Assuming similar diesel fuel prices, vegetable oil use would be expected to occur in the major producing areas first because of this difference in costs (assuming the market price is a good indicator of the marginal cost of producing additional vegetable oils). Production in New York State may occur but will probably not do so until diesel prices rise further. The prices used in the analysis would hold only for small changes in current cropping patterns. A major shift toward oilseed production would disrupt current supply-demand relationships.

Processing facilities are currently lacking in New York and surrounding states and would be needed for any future production. Economies of size appear considerable, but must be balanced against increased transportation costs as plant size increases. Possible future areas of research are to estimate demand for vegetable oils and the quantities that New York State farmers might produce as prices rise from current levels. These results would provide input into a more detailed study of optimal locations and sizes of processing plants. The results of the present study indicate that the necessary prices would have to be considerably above current levels, however.

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