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AGRICULTURALLY PRODUCED FUELS

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SUMMARY:
This paper discusses the status of development and potential production of vegetable oil, alcohol and methane as substitutes for fossil fuels in the United States. It is emphasized that for renewable fuels to make a significant contribution to energy use will require the development of every foreseeable alternative energy source.

KEYWORDS:
vegetable oil, alcohol, methane, alternative energy

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Agriculturally Produced Fuels

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The United States is almost totally dependent upon petroleum for its liquid energy source. Stout (1984) reports that 71.5 percent of our total energy is from oil and natural gas while only 2 percent comes from biomass. In 1989, the U.S. used about 3.2 million barrels/day of distillate fuel and 7.4 million barrels/day of gasoline. For agriculturally produced renewable fuels to make a significant contribution to this mammoth energy use would require the use of every foreseeable alternative energy source which can be developed. This paper will report on the status and contribution of three widely discussed alternative fuels from agriculture: vegetable oil, alcohol and methane.

Vegetable Oil Fuels

Vegetable oils have potential as a substitute for diesel fuel. Those with the greatest production potential are sunflower, safflower, soybean, cottonseed, rapeseed, canola, corn, coconut and peanut oil. Modifying these oils to produce the methyl or ethyl ester has been shown to be essential for successful engine operation over a long term (Zhang, 1988). Development of vegetable oil as an alternative fuel would make it possible to provide energy for agriculture from renewable sources located close to the area where it could be used.

As of 1982, the active crop land in the United States consisted of 382.8 million acres; an additional 21.5 million acres of crop land was idle. Assume that 1 acre of vegetable oil is capable of producing 100 gallons of oil. (rapeseed at 1 ton per acre is equivalent to 100 gallons of oil and approximately 1200 pounds of meal.) On this basis, if every acre of available crop land were to be put into rape production approximately 40,425 million gallons of fuel per year could be produced. This is equivalent to 1.6 times the annual consumption of diesel use in transportation.

Computations of the land actually available for vegetable oil production are complicated. Certainly land must be available for domestic production of food. It is also logical to assume that some production of food for export will continue to be needed. In 1990, 35 million acres were in the conservation reserve program and 24.8 million acres were in the set-aside programs (USDA. 1990). These two sources of idle crop land could produce 5.98 billion gallons of vegetable oil per year or 24 percent of the diesel used in transportation. An estimate of additional crop land potentially available for vegetable oil production was made by comparing crop production for several of the major crops

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with domestic use. Any production over domestic use was termed excess and using the national average production for that crop an estimate of excess crop production land of 65 million acres was calculated, see Table 1.

Table 1

Production, Domestic Use and Excess Production
of Selected Crops in the U. S.
(USDA, 1989)

CROP	PRODUCTION (mil. bu.)	DOMESTIC USE (mil. bu.)	EXCESS PRODUCTION (mil. bu.)	EXCESS LAND AREA (mil. acres)
Wheat	2108	1092	1016	26.95
Hard Red Winter	1019	512	507	13.450
Soft Red Winter	348	190	158	4.190
Hard Red Spring	431	280	151	4.005
Durum	93	50	43	1.141
White	216	59	157	4.164
Corn	7072	5964	1108	9.280
Sorghum	739	589	150	2.152
Barley	530	433	97	1.840
Soybeans	1923	1121	802	23.789
Rice	129.2 mil. cwt.	73.9 mil. cwt.	55.7 mi. cwt.	1.003
Total area used to produce excess crops				65.015

Providing sufficient liquid fuel to replace U. S. petroleum imports, and because of recent world events, that from the Arab Opec countries of Kuwait and Iraq is of especially high priority. These imports are shown in Table 2. The U.S. Distillate Fuel and Gasoline Fuel Use is shown in Table 3.

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. In 1981, the U.S exported 363 million gallons of vegetable oil, equivalent to 11 percent of the diesel fuel used in agriculture.

Table 4
U. S. Production of Vegetable Oil
1981
(USDA, 1983)

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

Vegetable oil has potential as one segment of the alternative energy picture. Realistically, vegetable oil could be used to replace the 3.4 billion gallons of diesel used per year in production agriculture. To do this would require 8%-10% of our agricultural land. About 1 out of every 4 acres of cropland in the U. S. would be required to replace the oil imported from Iraq and Kuwait in 1989, see Fig. 1. Reductions in land required would result from improved oil production which might occur through improved varieties or selection of higher yielding cultivars. Figure 2 shows how the required crop acreage would decline as yield improves.

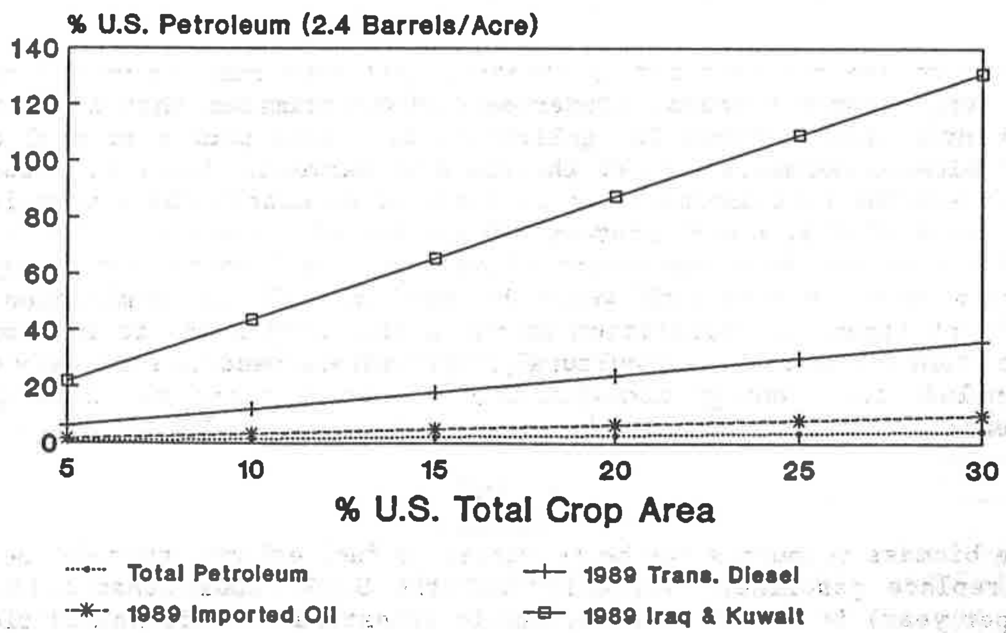

Figure 1. Potential production of ester of rape oil.

1989). In addition to corn, there are lignocellulosic feedstocks that can be converted to fuel ethanol and other products. Table 5 provides the most current data available on the availability of biomass resources in the United States. Total ethanol production varies depending on the availability of the particular resource and the conversion technology utilized.

In addition, there are other grains that could be processed to ethanol, and animal wastes (about 50 million T/yr (Bell, 1980)) and sewage sludge that are potential biomass resources. It is estimated that the set-aside acreage will increase from today's 40 million acres to 160 million acres over the next decade. If this does indeed happen, these additional acres could be used for biomass crop production and yield an additional 29-65 billion gallons of ethanol annually.

After removal of the ethanol, the remaining solid material represents an excellent combustion fuel (about 10,000 Btu/lb). This solid residue's primary component is lignin which offers potential as a feedstock for high value chemicals, such as phenol formaldehyde resins and polyols for urethane foam production.

Table 5
Estimated Total Ethanol Production

Biomass Resource	Million Tons/Year	Ethanol Yield Gal/Ton	Billion Gal. Ethanol/Year
Ag Residues	60-185	40-90	2-17
Forestry Residues	160-385	40-90	6-35
MSW	240	15-55	4-13
Set-Aside Land	240	40-90	10-22
Food Processing Waste	11	40-90	0.4-1
Surplus Corn			5-6
Total			27-94

[1]Diaz and Golueke, 1981(x 20% & 50% available)
[2]Zerbe, 1988
[3]Cook, 1988
[4]40 million acres planted with agricultural or short rotation woody biomass at an average yield of 6 t/acre results in 240 million tons of biomass per year.
[5]Weathers, 1989

Today we are producing about 1 billion gallons of ethanol a year, and most of this is being blended with our 114 billion gallons of gasoline that we use each year. If ethanol is blended with gasoline at a 10% rate, the market for ethanol would be 10 billion gallons. This amount of ethanol would require approximately 40 million acres of crop land to produce the feedstock. At a 20% blending rate, from the volatile solids of major animal types are also documented. These values may be combined with animal population data to determine the maximum potential methane production, TM (Tg/yr), for each animal type in the United States using

$$TM = 365 \times N \times VS \times B_o \times \rho \times 10^{-9} \qquad (1)$$

where, N is the number of animals, and ρ is the density of methane (0.662 kg/m^3).

Most of the available data relating to methane emissions to the atmosphere from animal wastes have been reviewed and compiled by Casada and Safley (1990). They presented estimates for the total animal waste production for the major livestock types in the United States, for each state, as well as estimates of the amount of the waste handled with the different types of waste management systems. After calculating the maximum potential methane production, we find a current potential by not including manure that is left on pasture, since that manure will not make it to a digester without major changes in animal production practices. Waste that is already handled with liquid systems would be the easiest to digest with the least change in production practice. Using just the amount of waste currently on liquid handling systems gives the minimum potential methane production in Table 6. If all animal waste currently collected in the United States were digested, the methane produced would have the energy equivalent of 95 million barrels of oil per year.

Table 6

Potential methane production from animal wastes

	Maximum Potential		Current Potential		Minimum Potential	
	Methane	Energy[1]	Methane	Energy[1]	Methane	Energy[1]
Type	Tg/yr	10^6 bbl/yr	Tg/yr	10^6 bbl/yr	Tg/yr	10^6 bbl/yr
Beef	13.3	108	2.5	20	0.1	1
Dairy	5.2	42	4.8	39	1.9	15
Swine	3.1	25	2.8	23	2.1	17
Poultry	1.5	12	1.5	12	0.2	1
Other	1.3	10	0.0	0	0.0	0
TOTALS:	**24.3**	**197**	**11.6**	**95**	**4.2**	**34**

[1]bbl = barrels of conventional crude oil (6.1 x 10^6 kJ/bbl).
Source: Casada and Safley (1990).

Use

The potential methane production in Table 6 does not address the question of economic feasibility, and little recent work has been done on the economics. In general, payback periods may range from 4 to 10 years depending on the size of the operation and the need for continuous supplies of energy (e.g. Safley and Lusk, 1990). Large operations with large continuous needs for energy will have

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