CONSIDERING PRODUCING ALCOHOL FROM POTATOES

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Introduction

There is a renewed interest in producing alcohol fuel from agricultural products. There are several reasons for this. First, we recognize that being dependent upon OPEC for about 50% of our liquid fuel is putting the United States into a more vulnerable position than ever before. Second, recent oil price increases have pushed the price of liquid fuel to a point where alcohol production may make more sense economically, especially with government subsidies. Third, the technology for alcohol production has advanced rapidly. Some of the plants that have been built are producing and are at a point where production records can be obtained, and the economic and technological feasibilities demonstrated.

The United States has an abundant supply of coal, but is short of liquid fuel. Eventually a significant amount of liquid fuel will be produced from coal. However, until the coal liquification technology is developed, alcohol fuel can be produced from agricultural products to ease some of the shortages.

In 1978 the United States produced a total of 18.25 Mi tons of potatoes. If the whole 1978 potato crop would have been used for producing alcohol, it would have produced 438 Mi gallons of alcohol. This would be enough alcohol for about 4.4% of the nation's gasohol (10% alcohol, 90% gasoline blend) with an all-gasohol program. For comparison, about 60% of the nation's corn crop would produce enough alcohol to provide the nation with 100% gasohol supply.

Potatoes are a high-yielding crop, especially when grown in the central Columbia Basin of Washington and Oregon. With yields of 50 tons per acre 1,200 gallons or more of 200 proof alcohol per acre can be produced. A 200 bushel per acre corn crop will produce only about 500 gallons of 200 proof alcohol. However, it must also be pointed out that it takes much more energy to produce, transport, and process one acre's potato production than it does for one acre's corn production.

The Question of Energy Efficiency

One consideration is the net energy efficiency of the potato-to-alcohol conversion process. Many studies have been done regarding energy inputs into alcohol production. Many assumptions must be made in these studies, and in the past many assumptions were based on old conversion process technology.

Critical items that must be considered in a detailed study are (a) the kind of energy used in crop production, transportation, and processing in the alcohol plant, (b) efficiencies of the various processes involved, (c) the processing and drying of the by-product, and (d) changes in the petroleum refining process which might be possible if alcohol is used as an octane booster when mixing it with low-octane gasoline.

The question of energy efficiency is not how much energy is used in producing one gallon of alcohol, but is a question of how much or how little liquid petroleum fuel is used. If we want to reduce our dependence upon imported oil, then we must minimize the use of petroleum fuel in growing and processing energy crops by substituting with more abundant energy sources for these operations where possible.

Energy Requirements for Crop Production

Energy requirements for potato production will vary widely depending upon where they are grown, how much irrigation water is applied, the type of irrigation system used, and the height to which the water needs to be lifted. The following energy use calculations are based on production figures from the publication titled Estimated Cost of Producing Fall Potatoes in the Columbia Basin (1).

1. Irrigation

   Assume center pivot system, 125 HP motor, run 1600 hours per season, 130 acres.

   $$\text{Energy used, KWhrs} = 125\ \text{HP} \times \frac{.746\ \text{KW}}{\text{HP}} \times 1600\ \text{hrs.} = 149{,}200\ \text{Kwhrs.}$$

   If a diesel engine were used, it would consume 13,000 gallons of diesel fuel during the season or 100 gal/acre. Energy required to pump the water at Grand Coulee Dam is not included in this analysis.

2. Fertilizer

   Assume the following applications:

   400 lbs. N, 200 lbs. P, and 400 lbs. K.

   Energy requirements for fertilizer production vary widely depending upon type of fertilizer used and production processes used in manufacturing.

   Production distribution energy for the fertilizer is calculated as follows:

   $$400\ \text{lb. N} \times \frac{.12\ \text{gal oil}}{\text{lb N}} = 48\ \text{gal}$$

   $$200\ \text{lb. P} \times \frac{.06\ \text{gal oil}}{\text{lb P}} = 12\ \text{gal}$$

   $$400\ \text{lb. K} \times \frac{.03\ \text{gal oil}}{\text{lb K}} = 12\ \text{gal}$$

   TOTAL = 72 gal diesel fuel equivalent/acre

3. Seed Pieces

   Production and transportation energy for seed potatoes are high, especially if transportation distances are long.

   2 tons/acre x 4 gal/ton = 8 gal/diesel fuel equivalent/acre

4. Tractor and Equipment Operation

   Cultural practices and equipment operation will vary from area to area and with individual growers. The operations and fuel consumption listed below are assumed to be "typical" for the Grant County area.

Operation	Gal. Diesel Fuel Used per Acre
Plowing	3.8
Disking and packing	3.3
Planting	2.4
Fertilizer application (custom)	1.0
Cultivate	1.9
Spraying, 2X (custom)	2.0
Harvesting	8.5
TOTAL	22.9 Gal/Acre

5. Transport and Storage

Operation	Gal. Diesel Fuel Used per Acre
Transport seed to planter	4.6
Transport to storage (harvest)	15.0
Pick-up use (management)	2.5
Storage	2.0
Transport to plant (20 min.) 2 loads/acre @ 7.5 gal/load	15.0
TOTAL	39.1 Gal/Acre

6. Total Energy for Feedstock Production and Transportation

Irrigation	100 Gal/Acre
Fertilizer	72
Seed	8
Tractor and Equipment	22.9
Transport and Storage	39.1
TOTAL	242.0 Gal/Acre

$$242 \text{ Gal/Acre} = \frac{242 \text{ Gal/Acre}}{50 \text{ Tons/Acre}} = 4.84 \text{ Gal/Ton}$$

To facilitate further calculations, the above figure should be expressed in Btu required for the production of feedstock per gallon of alcohol produced.

Assuming that one ton of potatoes will yield 24 gallons of alcohol, then the fuel input per gallon of alcohol is:

$$\frac{4.84 \text{ Gal oil/ton}}{24 \text{ Gal alcohol/ton}} = 0.20 \text{ Gal oil/Gal alcohol}$$

$$\text{Input} = 28,000 \text{ Btu/Gal alcohol}$$

Energy Requirements for Processing at Alcohol Plant

It is very difficult to obtain actual energy figures and production data from plants that are producing alcohol from potatoes. Also methods and equipment for some of the processes are rapidly changing. The major energy-intensive plant operations are feedstock preparation, distillation, and by-product recovery. Other energy needs are electricity for motors and other electrical equipment, and miscellaneous uses.

Potatoes are more difficult to process to alcohol than is corn because potatoes contain an excessive amount of water. Recovery (dewatering) of the by-product is also more difficult for potatoes than for corn because the potato by-product contains more fine material. For example, a screw-type dewatering extruder that is used for corn cannot be used for potato by-product.

Several sources list estimated energy requirements for processing corn and other crops into ethanol. The basic processing energy requirement estimates for potatoes are shown in Table 1.

Table 1. Basic Processing Energy Requirement Estimates

	Estimates from Various Sources, Btu/Gal		
Inputs	Krochta (2)	USDA (3)	Cole (4)
Feedstock preparation & cooking	9,000	3,700	
Distillation	20,000	28,000	
Anhydrous column		20,000	
By-product recovery & drying	8,000	16,000*	
Electricity	10,000		
Miscellaneous	10,000		
TOTAL	57,000	67,700	35 - 70,000**

*Adjusted for potato feedstocks, includes electrical energy required in the recovery and drying processes.

**Feasibility study including various manufacturers of equipment.

Using the figures in Table 1 and the energy input for crop production calculated earlier in this paper, we can now establish an overall energy balance for the production of anhydrous alcohol from potatoes grown in the Columbia Basin. Table 2 summarizes the energy input and output data. The Table also illustrates that a break-even to a positive energy balance exists for the conversion of potatoes to anhydrous alcohol. Feeding the by-product in a wet condition increases the energy balance. However, it may not be practical to feed the by-product in a wet condition. Drying the by-product would certainly increase its marketing flexibility.

Another reason for a positive balance is a high crop yield per acre. If the yield were reduced from 50 tons per acre to 40 tons per acre, the energy balance would be near break-even.

Table 2. Energy Balance for Anhydrous Alcohol Production From Potatoes Grown in the Columbia Basin

	Energy, Btu per Gal Ethanol		
Inputs	Krochta (2)	USDA (3)	Cole (4)
Feedstock Production	28,000	28,000	28,000
Processing (incl. drying of by-product)	57,000	67,700	35-70,000
Total Input	85,000	95,700	63-98,000
Outputs			
Ethanol	84,000	84,000	84,000
By-Product	20,000	20,000	20,000
Total Output	104,000	104,000	104,000
Output/Input	1.22	1.09	1.06 - 1.65
Output/Input if By-Product is not dried	1.35	1.19	1.16 - 1.89

Specific Problems with Potato Processing

Potatoes contain about 80% water which must be processed in the plant. A certain amount of water is required during the fermentation process in order to keep the alcohol concentration in the beer below 12%. When processing potatoes the excess water in the feedstock results in an alcohol content in the beer of 6% - 8%. As a result, unneeded water is run through the cooking, cooling, and distillation processes, resulting in reduced output per hour, and increased energy consumption per gallon of alcohol produced.

Quality of Feed By-Product

Compared to grain by-product, the dried potato by-product has a significantly lower protein content and contains significantly less TDN (Total Digestible Nutrients) and less energy than does distillers dried grain. Table 3 shows the nutrient composition of distillers dry residue of potatoes and distillers dried grain for corn (5).

Economic Considerations

An economic analysis depends upon assumptions made regarding the price of potatoes delivered to the plant, the cost of processing the potatoes into alcohol, and the credits or price received for the by-product. At this time all of the above listed items must be estimated because we do not have enough experience in processing potatoes, and cost figures are not available for potatoes. Generally it is more costly to process potatoes because they contain an excess of water which reduces the plant capacity as well as the process efficiency. The by-product is less nutritious than that from corn or grain as illustrated in Table 3. A market for potato residue (dried or wet) has not been established. Until a demand is established, the prices for this product would be severely depressed.

Table 3. Typical Nutrient Composition of Distillers Feeds

	Corn D. D. Grain		Potatoes D. D. Residue	
	%	KCal/Kg	%	KCal/Kg
Dry Matter	93.8		95.7	
Ash	2.2		6.7	
Crude Fiber	12.6		20.6	
Ether Extract (Fat)	9.3		3.1	
N-Free Extract	41.9		42.4	
Protein	27.8		22.9	
Cattle TDN*	79.0	3,480	61.0	2,690
Sheep TDN	76.6	3,380	61.8	2,730
Swine TDN	92.5	4,080	74.6	3,291

*TDN = Total Digestible Nutrients

Source: Atlas of Nutritional Data on U. S. and Canadian Feeds, National Research Council, 1971.

Preliminary information obtained from one alcohol producer indicates that at today's alcohol production costs and alcohol prices, it would be economical to produce alcohol from potatoes at $20.00 per ton delivered to the plant. If it is possible to produce potatoes for this price still remains to be evaluated. Table 4 illustrates that with high-yielding varieties and low production costs, it may be possible to lower the production costs to $20.00 per ton.

Table 4. Minimum Potato Price Requirements for Various Yields and Production Costs

Yield Tons/Acre	Price, $/Ton required for Production costs per acre of:		
	$1000	$1250	$1500
40	25	31.3	37.5
50	20	25	30
60	16.7	20.8	25

In order to an alcohol plant to operate economically, it would need to operate 24 hours a day, year round. It would need to be supplied with potatoes for an eight to nine month period per year. For the remaining period of the year grain could be processed. Growers would need to make a commitment to the plant and vice versa. One could not depend upon cull potatoes for instance.

Conclusions

Growing potatoes for an energy crop should be investigated further and its feasibility studied. Items of special interest are:

1. High-yielding varieties produce large amounts of alcohol per acre, 1000 gallons or more.

2. High-yielding varieties reduce the production cost per ton.

3. We need to establish the feed value and market for potato by-product.

4. A continuous supply of feedstock is needed.

5. Transportation distances of potatoes should be kept very low to minimize transportation costs and energy requirements.

6. Potatoes have a high water content which reduces plant capacity and efficiency. Mixing potatoes with ground corn may eliminate excess water.

References

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