AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

AGRICULTURAL ECONOMICS
FACT SHEET No. 35—1981

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Ethanol Production From Field Crops

A major world concern of the 1970s was petroleum fuel's declining supply and rising price. Fossil fuel costs probably will continue to increase through the 1980s, which has prompted consideration of alternative fuels derived from sources other than petroleum. Production of ethyl alcohol (ethanol) from agricultural crops is one such alternative. Ethanol can be used as a fuel alone but most often is mixed with conventional petroleum fuels such as gasoline to extend the supply.

In this fact sheet we do not intend to debate whether producing ethanol from agricultural crops is advisable from the standpoint of energy return per unit of energy invested. We will discuss the levels of ethanol production that might be expected from various field crops in Minnesota and the costs of producing these crops once the decision has been made to produce ethanol for fuel. We will also consider other factors that are important in deciding which crop to grow as a feedstock.

Ethanol Production Process

The following simplified equations summarize the chemical conversions involved in the production of ethanol from agricultural feedstocks:

1. Starch or cellulose (in feedstock) + water $\xrightarrow{\text{enzyme}}$ sugars
2. Sugars $\xrightarrow{\text{yeast}}$ ethanol + carbon dioxide

Ethanol production usually consists of several intermediate steps: grinding of the feedstock, cooking to solubilize and gelatinize the starch, starch hydrolysis, fermentation, and distillation. Further distillation and dehydration may be required if a 95 percent (190 proof) or higher concentration of ethanol is desired.

"Stillage," a by-product of ethanol production, is a thin slurry containing unfermented starch, fiber, protein, and ash. Stillage can be dried and concentrated into "distillers dried grains and solubles," which has a high protein concentration (approximately 28 - 36 percent) and is suitable for a ruminant livestock feed.

Ethanol Production From Field Crops

Ethanol can be produced from a wide variety of field crops and residues containing sugars, starch, or cellulose. The most common feedstock used is corn grain, which contains a high concentration of starch. Since the conversion process for cellulose-containing feedstocks is still being developed, we will consider grains and crop products that contain mostly sugars or starch.

Some interest has been expressed in adopting new or uncommon crops for feedstocks such as the fiber crops kenaf (*Hibiscus cannabinus* L.), roselle (*H. sabdariffa* L.), and sunn hemp (*Crotalaria juncea* L.). Such crops are not grown to any extent in Minnesota and do not represent likely major feedstocks for ethanol production in the near future. We will basically consider crops that grow successfully in Minnesota and are familiar to farmers. Exceptions are sweet sorghum and grain sorghum, which do not occupy large acreages in Minnesota but have drawn attention as potential feedstocks.

Potential Ethanol Yield

The quantity of ethanol produced from an acre of crop feedstock is an important consideration. It can be calculated from two factors: (1) how much feedstock can be produced per acre (yield), and (2) how much ethanol can be made from a given quantity of feedstock (conversion rate). Table 1 lists yields, conversion rates, and ethanol productivity values per acre that might be obtained in various regions of Minnesota. Because of limited commercial grain and sweet sorghum production in the state, yields of these crops have been estimated from research at branch experiment stations.

Highest production of ethanol per acre will be achieved with high dry matter yield crops such as corn, potatoes, sugarbeets, grain sorghum, and sweet sorghum. Table 1 shows that ethanol productivity per acre throughout Minnesota will vary as the yields of the crops change.

Feedstock Cost

The cost of producing a feedstock is important. Table 1 summarizes production costs for the crops listed and the resulting feedstock costs per gallon of ethanol produced. These costs are derived from the "1981 What to Grow" budgets, and may vary with changes in the production system or input costs. All crops except sweet sorghum include a six-month storage cost on the assumption that a feedstock supply would be needed year-round for the ethanol plant. Feedstock cost is the most important cost in determining the economic feasibility of an ethanol plant. Value derived from by-products of the ethanol production process, which can partially offset costs, has not been included in table 1. Other costs associated with building and operating a plant must also be considered.

Availability and Storage of Feedstock

The availability of a feedstock and its storage qualities determine the length of time during the year that an ethanol production plant can operate. Longer-term storage of grains is not a problem if precautions are taken to prevent deterioration. Crops that contain high concentrations of sugars, such as sugarbeets and sweet sorghum, have a much shorter storage life in their harvested form. They can be partially processed to increase their longevity. Sole use of sugar crops means that an ethanol plant could be operated only for a limited season, although supplemental feedstocks could be utilized to extend

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the operating period. Potatoes usually have a six-month storage period before serious deterioration begins.

Damaged feedstock such as sprouted or moldy grains and off-grade potatoes can be used for ethanol production, although their conversion rate to ethanol will decline with the loss of starch and sugars caused by deterioration.

Distiller's By-product

Differences in the chemical composition of various feedstocks results in different compositions of the distiller's by-product. This is important in establishing the economic or feed value of the by-product. When grains are used as the feedstock, the stillage may be fed directly or processed into a high protein feed. Sugarbeet by-product, as a commercial feed ingredient, is of slightly lower value than distillers' dried grains. However, further consideration and marketing of solubles may give a higher overall value for the sugarbeet by-product than for the grain by-products. Sweet sorghum by-product has not been well tested, but would appear to have a lower feed value than grain by-product. The by-product of potatoes has a lower protein concentration than corn distillers' dried grains and solubles and consequently a lower feed value.

Removal of Crop Residues

Crop residues may have potential as an energy source used either as a fuel for powering ethanol production plants, or directly as a feedstock for ethanol production once technology for cellulose conversion is developed. But crop residues also have considerable value in controlling soil erosion and supplying plant nutrients to the soil.

A ton of crop residue per acre on the soil surface can reduce soil loss by water erosion as much as 65 percent. The United States Department of Agriculture recently estimated that 56 million tons of crop residue could be removed from Corn Belt soils without causing soil erosion to exceed the tolerance limit. Corn residue would make up a majority of this amount. These available residues would be from relatively level soils where the erosion hazard is minimal.

Removal of residue would probably increase fertilizer use. If residue from a 150 bushels per acre corn crop was totally removed and the consequent loss of nutrients by increased water erosion considered, 130 - 190 pounds per acre of nitrogen and 25 - 40 pounds per acre of phosphorus might be taken from a field. These are nutrients that must be supplied to subsequent crops through fertilization.

Residue management by conservation tillage and increased use of erosion control practices such as contour cropping, strip cropping, and terracing will be necessary if all or part of the crop residue on a field is removed for use in ethanol production. Fields that have a serious wind or water erosion potential because of soil type or slope will not be able to contribute crop residue. If crop residue is needed for runoff or erosion control in a field and feasible control alternatives are not available, the residue should remain on the land.

Table 1. Total costs per acre, yields, estimated gallons of ethanol per acre, and resulting feedstock cost per gallon of ethanol for selected crops in five regions of Minnesota*

	Total cost	Yield (bu)	Conversion rate** (gal/bu)	Ethanol productivity (gal/acre)	Feedstock cost/gal ethanol
Southeast					
Corn	$340	125	2.4	300	$1.13
Spring wheat	173	40	2.6	104	1.66
Oats	167	90	1.0	90	1.86
Sweet sorghum	282	9 (ton)	34.0 (gal/ton)	306	.92
South Central					
Corn	$333	135	2.4	324	$1.03
Spring wheat	205	55	2.6	143	1.43
Oats	199	90	1.0	90	2.21
Sugarbeets	439	17 (ton)	22.1 (gal/ton)	376	1.17
Grain sorghum	293	90	2.2	198	1.48
Sweet sorghum	314	9 (ton)	34.0 (gal/ton)	306	1.03
Southwest					
Corn	$262	100	2.4	240	$1.09
Spring wheat	164	45	2.6	117	1.40
Oats	150	80	1.0	80	1.88
Barley	169	65	1.9	124	1.36
Grain sorghum	210	80	2.2	176	1.19
Sweet sorghum	229	8 (ton)	34.0 (gal/ton)	272	.84
West Central					
Corn	$226	80	2.4	192	$1.18
Spring wheat	135	40	2.6	104	1.30
Oats	125	70	1.0	70	1.79
Barley	130	55	1.9	105	1.24
Grain sorghum	178	70	2.2	154	1.16
Northwest					
Corn	$248	90	2.4	216	$1.15
Spring wheat	165	45	2.6	117	1.41
Oats	147	70	1.0	70	2.10
Barley	160	65	1.9	124	1.29
Potatoes	582	180 (cwt)	1.1 (gal/cwt)	198	2.94
Sugarbeets	392	17 (ton)	22.1 (gal/ton)	376	1.04

**All crops, except sweet sorghum, assumed stored average of six months at 1.25 percent of their value per month. Production costs derived from "What to Grow" budgets; see Agricultural Economics Fact Sheets No. 22-33, Agricultural Extension Service, University of Minnesota, 1981.*

***These rates assume in most cases conversion to 198 proof (99 percent) ethanol.*

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Norman A. Brown, Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108.
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