Fuel alcohol from biomass

Robert G. Curley

Petroleum shortages and price increases have stimulated considerable interest in the production of ethyl alcohol from biomass (plant material)—using certain agricultural crops and crop residues.

Some people view biomass alcohol as a logical solution to the nation's energy problem. Others see it as having a very limited potential. Some farmers view biomass alcohol production as a potentially important outlet for certain commodities and a means of increasing prices for those commodities.

The true potential for biomass alcohol is difficult to determine for several reasons. First of all, there are many variables in the production and use of alcohol that must be taken into account. Secondly, the economic picture fluctuates because of inflation and rising fuel prices. A third reason is the biased evaluation and conclusions that sometimes receive widespread publicity.

It is important to keep the biomass alcohol fuel picture in perspective. The United States consumes approximately 100 billion gallons of gasoline per year. To replace 10 percent of this with ethanol from corn—10 billion gallons per year—would require approximately 50 percent of the corn acreage based on 1978 data. It is obvious that any large-scale conversion of agricultural commodities, such as grain, will involve a trade-off between feed or food production on the one hand and fuel on the other. The production of ethanol from agricultural commodities is a major public policy issue.

There is a need for objective scientific research and analysis on the subject and also a need to provide the public with information that is as factual and reliable as possible. In an attempt to address the latter need, Cooperative Extension and University Extension co-sponsored a January conference at the University of California, Davis, on biomass alcohol. The following articles are based on papers presented at that conference.

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Barley straw and some other crop residues may eventually offer an economical source of feedstocks for alcohol processing plants.

Harvesting crop residues for alcohol production

George E. Miller, Jr.

An estimated 7 to 15 percent of energy now used in California could come from cellulosic biomass, if fully utilized. From 20 to 35 million tons of this underutilized residue from forest and farming operations are produced annually in California; quantities from biomass farming on underutilized land would be substantially larger but are unknown at this time.

The term "cellulosic biomass" for the purpose of this discussion is defined as organic plant materials that are unused or underused by-products of crop or forest production and harvest operations, and products from biomass farming. The definition should also be extended to include certain organic waste products from animal and poultry production and forest and agricultural processing plants, such as sawmills, planing mills, feedlots, poultry production facilities, canneries, packinghouses, cotton gins, feed and grain mills, and seed refining plants.

A major economic advantage of these latter production and processing wastes is that they are already collected at central points. Where sufficiently large quantities are available without densification or transport, these materials will undoubtedly be used first as energy values and waste disposal costs are recognized, and the necessary technology for utilization can be harnessed. It is a rare occasion, however, when on-site energy needs and the supply of cellulosic biomass are in perfect balance. The surplus or deficiency then presents some of the same problems associated with large quantities of crop and forest residues that are now underutilized or materials that might be produced under biomass farming.

In addition to the need for the energy in these crops and forest residues, they present a disposal problem. Every year 5 to 6 million tons of crop and forest residues are open-field-burned. The concern about aesthetics, effects on visibility, odors, and possible health effects on sensitive citizens makes it imperative that pollutants generated by agricultural burning be minimized wherever technologically and economically

Upper left: Shredder could be used in orchard brush management during the winter and in forests and brushlands in the summer, providing nearly year-round supplies of biomass feedstocks.

Upper right: Hay cuber with a new type of die may represent the needed breakthrough in densifying rice and other cereal crop straws, without expensive binders, for transport to alcohol plants.

Right: Tub grinder, originally designed for hay and straw, shows promise in preparing orchard prunings, forest slash, and brush for alcohol production.

feasible. Legislation is pending on this subject. Legislation is also pending at state and federal levels to encourage production and utilization of renewable energy resources.

Why don't we just use all this material and stop talking about it? There are a number of reasons why we haven't and they vary to some extent with the type of cellulosic biomass. The primary problems are collection costs and the need for continuous supplies.

Collection costs

The largest quantities of these materials are scattered out in the fields or forests and require the application of some collection and modification technology. As they are left behind after the crop harvest, orchard pruning, or logging operation, they are not in a physical form that can be readily handled, transported, economically stored, or used. For efficient transport and storage, they must be chopped, chipped or ground, and cubed, pelletized, baled, or otherwise densified.

Continuous supplies

Most alcohol plants or other large potential users of biomass will need a year-round supply of feedstock(s) and energy resources for the process to maintain an economically efficient operation. The heavy capitalization costs can be justified only by continuous operation. Unfortunately, few, if any, individual sources of biomass can provide this continuous supply without storage, either at the production site, at intermediate storage points, or at the utilization site.

Crop biomass becomes available at harvest. In the case of barley and wheat, in a double crop rotation, the residue has to be removed within a very few days, as is done by open field burning. (The soil has to be prepared and the second crop planted so that it will have time to mature before the cool fall weather.)

Removing the biomass will require large numbers of baling or other densification machines for short periods of time. If the material can be chopped rapidly and delivered off the field to a semistationary cubing or other densification unit, the densifier can be run 24 hours a day on straw that is collected at the optimum moisture content for densification and storage.

Rice straw presents some special problems because of uncertain weather in the fall, but it also provides an additional work period for the densification equipment. Special flotation equipment will undoubtedly be required at extra cost if large quantities are to be guaranteed. A recent test of a hay cuber with a new type of die appears to offer the possibility of making dense cubes of rice straw and other cereal crop straws without the need for expensive binder materials. This could be a real breakthrough. More testing of a sustained nature is required to determine maintenance problems and costs.

Orchard prunings may require equipment like that which might be used in the forest slash recovery systems. As in the case of rice straw, this could extend the operating season for portable chippers, hogs, or hammermills. Such equipment could work in the forests and foothill brushlands in the summer and desert brushlands and orchard brush management during the winter, when logging typically is reduced, if not stopped completely. A recent test of two tub grinders originally designed for hay and straw indicates a potential for this type of machine in orchard, forest slash, and brush utilization. A prototype windrow pickup and chipper system has been developed in Delano, California, and is currently being tested for this purpose. Other units are under study and development at other locations throughout the United States.

Costs have been developed on a theoretical basis for baling straw-type biomass; they currently range from $25 to $40 per ton delivered 25 miles from the point of production, not including profits. Orchard prunings, brush, and forest slash could be hammermilled and delivered for about $20 to $30 per ton, also not including profits.

To date these costs have been too high, and no ready markets have been found. Alcohol production could be a major market. It is also not clear who is to bear the costs or portion of costs if the material is not competitive with other fuel or feed stocks. Certainly, cellulosic biomass can compete with electrical energy and Middle Eastern or Alaskan oil. As a renewable energy source and with the benefits to air quality when compared with open field burning, it may make economic sense in some applications, later, if not at this time. We need a few more technological breakthroughs and economic feasibility studies on extended runs with the new collection and densification methods and then some stable economic markets for the products. We have some serious hurdles to get over yet, but they are becoming fewer and not quite as high as they have been, with the rapidly increasing costs of energy and fiber.

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Energy analysis for ethanol

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A major question in the production and use of fuel-grade ethanol is whether or not it yields a net energy gain after accounting for the fossil energy input required for biomass production, harvesting, transportation, and conversion. Two recent studies concluded that a net energy loss resulted in industrial-grade ethanol production from corn. Use of fossil fuel was assumed for all energy inputs.

We have extended the effort made by these previous studies to include the effects of biomass raw material, production area, process efficiency, ethanol product, byproducts, and use of nonfossil fuels for processing.

Biomass raw material

Ethanol can be produced from a wide range of feedstocks based on sugar, starch, or cellulose; sugar and starch feedstocks are the most widely used. Corn, grain sorghum, wheat, potatoes, sugarbeets, sugarcane, and molasses are commonly considered for fermentation to ethanol, and work is under way to improve the efficiency of ethanol production from cellulosic residue feedstocks, such as corn stover and sugarcane bagasse.

The energy input to produce these raw materials varies between 13 and 90 percent of the energy content of a gallon of alcohol, depending on the crop, growing region, and cultural practices used. In addition, the energy input for biomass raw materials such as molasses and corn stover depends very much on agreed-upon accounting methods. Some have argued that both materials should be regarded as waste residues and, therefore, not subject to an energy input accounting. However, because molasses is marketed as an animal feed, a production energy input has been calculated based on the energy required to replace it with another feed material, such as corn. For materials like corn stover, only collection and transportation have been included.

Converting biomass to ethanol

When using grains like corn, grain sorghum, or wheat for feedstock, preparation for fermentation involves enzyme propagation for starch breakdown to fermentable sugars, yeast propagation for fermentation of the sugars to ethanol, grain grinding to expose starch, and grain cooking and enzyme addition to convert the starch to sugars. The grinding and cooking steps for potatoes vary from those of grains because of the potatoes' size and moisture content, but they require a similar preparation energy input.

Using sugarbeets or sugarcane for feedstock eliminates the need to convert starch to sugar. However, other steps are required to produce the sugar juice for fermentation. The preparation energy input for these steps is probably quite close to that for grains.

Molasses, which is approximately 50 percent sugar, only has to be diluted before being fed to the fermentor. Thus, essentially no preparation energy is required.

The preparation energy required to convert the cellulose contents of residues like corn stalks to fermentable sugar has not been well established. Besides cellulose, such materials contain enough hemicellulose and lignin to yield products with energy contents equal to that of the ethanol derived from cellulose. One suggested approach for separating the cellulose, hemicellulose, and lignin from each other involves several preparation steps: (1) chopping the residue material to small particle size; (2) dissolution and hydrolysis of the hemicellulose with a warm alkaline or dilute acid solution to pentoses; (3) dissolution of the crystalline cellulose from lignin with an appropriate solvent; followed by (4) precipitation of the cellulose in an amorphous, exposed form; and (5) hydrolysis by acid or enzymes to glucose. The pentoses can be fermented or converted to useful chemicals such as furfural, while the glucose is fermented to ethanol. The energy input for this longer, more complex preparation is estimated to be two to four times that for grain preparation.