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The Future is Now: What You Need to Know About Ethanol

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Introduction

Nearly all of the ethanol manufactured in the United States today comes from corn. Ethanol from corn is often referred to as first generation biofuel. Corn is relatively simple and inexpensive to distill into ethanol and to date has been the crop of choice for expansion of the ethanol markets. Corn will continue to play an important role in U.S. ethanol production. However, second generation biofuels, derived from biomass feedstocks, is where future expansion in the ethanol industry will occur. Biomass feedstock is typically derived from agricultural plants and from wood grown in forests, as well as from waste residues generated in the processing or use of these resources.[1]

Plant cells contain cellulose, hemicellulose and lignin in cell walls (see Fig. 1). Cellulose and hemicellulose are made up of linear and branched chains of sugars. Plant cell walls can be broken down to expose the cellulose and hemicellulose, which can then be converted into basic sugars. The sugars can then be fermented into ethanol and other biobased products, much as corn ethanol is produced. Conversion rates for various processes and feedstocks vary tremendously. It is estimated that it will take a billion tons of biomass feedstocks per year to meet production goals set forth in the Energy Independence and Security Act of 2007. This goal seems lofty, but it is quite realistic, although it will require a diverse portfolio of feedstocks.

Process

Feedstocks can be processed in the biological platform and the thermochemical platform. The biological platform utilizes biochemical processes to break down cell walls and expose the cellulose and hemicellulose for degradation by enzymes into individual glucose molecules. The thermochemical platform employs pyrolysis or gasification to produce syngas. The syngas is then assimilated into various fuels and products. Both of these processes have been proven in the lab and are not new technology — they have been utilized for many years. However, developing efficient and cost-effective technology to process large volumes of biomass has been challenging. Scientists in the private and public sectors are working diligently to address these challenges. As new discoveries are made, we will start to see cellulosic ethanol production occur in the United States.

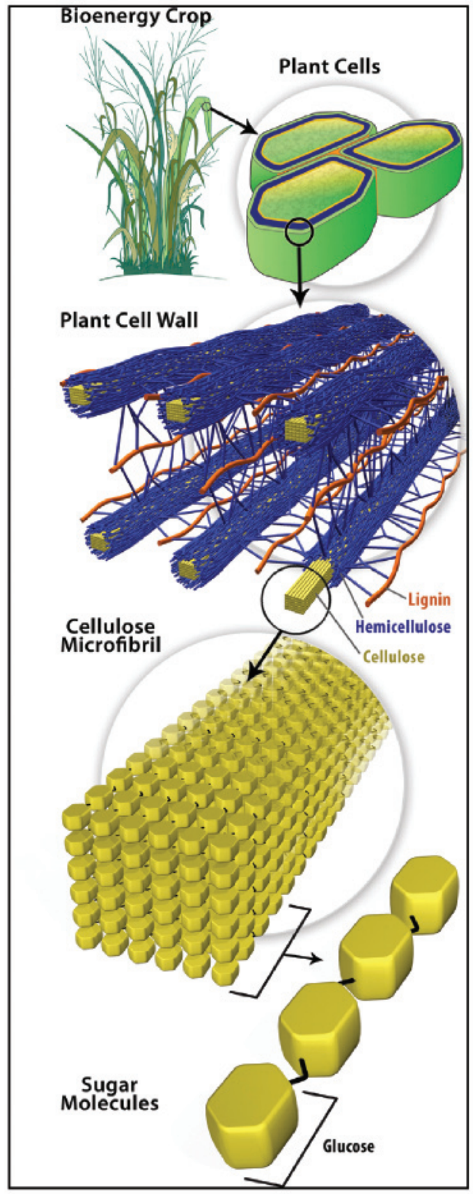

Figure 1. Plant cells contain cellulose and hemicellulose, which are made up of sugar molecules.

Source: Genome Management Information System, Oak Ridge National Laboratory

Feedstocks

A number of feedstocks can be used to supply biomass for cellulosic ethanol processing. The primary feedstocks being considered currently include switchgrass, miscanthus and other warm season grasses; corn stover; and poplar; and willow. Each of these feedstocks is being evaluated for its characteristics and production challenges.

An ideal feedstock crop would be high–yielding and easy to produce, require low inputs and be conducive to conversion into ethanol. Though the perfect crop probably doesn't exist, it makes sense to discuss what characteristics would make a feedstock an ideal crop (Figure 2). The attempt to find a crop that meets as many of these characteristics as possible is the aim much of the research going on throughout the United States.

Characteristics of an Ideal Energy Crop

- high yield
- efficient solar capture
- water use efficiency
- nutrient use efficiency
- pest resistance
- perennial growth habit
- nutrient cycling
- amenable to existing farm equipment
- non-invasive
- end use quality

Figure 2. Characteristics of an ideal energy crop.

A study commissioned by the U.S. departments of Energy and Agriculture in 2005 estimated that it would take 1 billion tons of biomass to meet the renewable fuel objectives set forth in our federal energy policy. This study, coined the "Billion Ton Study,"[2] suggested that 998 million and 368 million tons of agricultural and forest resources, respectively, can be sustainably produced and harvested annually.

Potential Production

Ethanol production varies widely with various feedstocks. Currently, the single most important factor determining ethanol output is biomass yield. The more biomass we can produce per acre, the more ethanol we can produce.

There are modest differences in cellulose, hemicellulose and cell wall structure between various feedstocks. The processes and enzymes that are currently employed to convert biomass into ethanol do not differentiate between feedstocks. As a general rule, we can produce about 72 gallons of ethanol per dry matter ton of feedstock, no matter what the feedstock is.

As new discoveries are made, it is possible to envision a set of processes and enzymes that are designed specifically for a particular feedstock. In this case, it would be desirable for an ethanol plant to utilize one feedstock. This could affect the diversity of species being planted and harvested to supply ethanol plants. A change in crop diversity could have environmental and ecosystems impacts.

Adaptation of Ethanol Plants

Nearly all of the operating ethanol plants in the United States utilize the biological platform to process corn into ethanol. This is particularly helpful because part of the process of converting cellulose into ethanol is the same as that for corn (fermentation, distillation and drying). Two precursor steps are needed for cellulosic feedstocks: pretreatment and hydrolysis. Pretreatment breaks down the cell walls and exposes the cellulose and hemicellulose. Hydrolysis breaks cellulose and hemicellulose down into their individual sugars. The sugar can be fermented, distilled and dried using the same equipment used in corn ethanol production.

Though this sounds simple, a significant investment in infrastructure would need to happen at an ethanol plant to conduct the two precursor steps. As more efficient processes are discovered, it will become more feasible for an existing ethanol plant to make this investment.

Sources:

[1] Mabee, W. E. 2006. *Ethanol from Lignocellulosics: Comparing biofuel technology options*. IEA Task 39 Report T39-P4.

[2] U.S. Department of Energy and U.S. Department of Agriculture. 2005. Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply.