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Session 1

Thermal, Chemical, and Biological Processing

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This session focuses on processing steps required to convert the carbohydrates of biomass into fuels and chemicals. For illustrative purposes, Fig. 1 shows a representative block flow diagram for a bioethanol process. (Of course, other approaches may be taken as well.) First, the biomass is pretreated to render it more digestible. Then enzymes are added that hydrolyze cellulose and hemicellulose into sugars. Finally, microorganisms (e.g., yeast) ferment these sugars to ethanol, which is recovered by distillation. The papers in this session describe various aspects of the process shown in Fig. 1, such as new developments in pretreatments, models of the saccharification and fermentation steps, enzyme recovery, combined enzyme/ethanol production, and a process that allows ethanol to be produced from biomass contaminated with radioactivity.

The Ammonia Fiber Explosion (AFEX) process has been optimized to pretreat corn fiber, a residue from corn wet-milling operations. The corn fiber was treated with liquid ammonia at 90°C; then the pressure was instantaneously released causing the corn fiber to explode. The resulting material was very digestible. Recombinant *Saccharomyces* strain (1400pLNH32) fermented both hexose and xyloses to ethanol with high efficiency.

Dilute-acid pretreatment allows fairly selective removal of hemicellulose from biomass, but the remaining solids are high in lignin. By removing the lignin with ammonia recycled percolation (ARP), the remaining solids are relatively pure cellulose. Thus, the three dominant components of biomass (cellulose, hemicellulose, lignin) are separated into relatively pure fractions. Because the lignin is removed, enzymatic saccharification of the relatively pure cellulose requires less enzyme and allows for better enzyme recovery. When conditions are properly optimized, lime pretreatment significantly increases the digestibility of herbaceous biomass. Many previous studies of lime pretreatment used suboptimal conditions; therefore, it has unfairly acquired a reputation for being a poor pretreatment agent compared to other alkalis (e.g., sodium hydroxide, ammonia). After the pretreatment, spent lime can be recovered by carbonating the wash water to form calcium carbonate, which is subsequently recovered in a lime kiln.

Kinetic models of the saccharification and fermentation portions of biomass processes are important design tools; in addition, models can bring fundamental insights into the process. A two-phase dynamic model accounts for the heterogeneous nature of biomass. This model describes enzyme adsorption with subsequent hydrolysis of the biomass and allows for a variety of particle geometries. It successfully describes the anaerobic digestion of cellulose and sludge.

Enzymes are a significant cost in the process shown in Fig. 1. A novel process allows the enzymes to be recovered and recycled that potentially will lower costs. This process precipitates the enzymes with subsequent recovery using continuous-column flotation.

Another approach to lowering the cost of enzymes is to consolidate enzyme production and fermentation into a single step. An important challenge of this approach is to obtain high enzyme productivity in the presence of high ethanol concentrations. New developments have shown that inhibition of *Clostridium thermosaccharolyticum*, which is generally attributed to ethanol, may actually be due to an insufficient nutrient supply or the accumulation of ions used to maintain a neutral pH.

The recent release of radioactivity from Chernobyl has contaminated vast regions of Russia. The biomass from these regions is radioactive, and hence, has little value. A process such as that shown in Fig. 1 allows the radioactive ash to be separated from the digestible portions of the biomass, thus having the double benefit of removing radioactivity from the land and producing useful fuels and chemicals from the biomass.

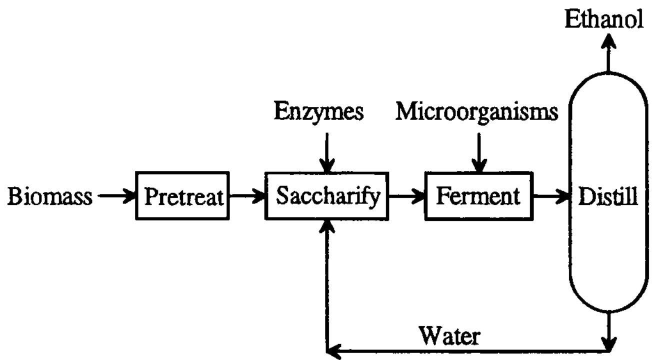

Fig. 1. A process for converting biomass to ethanol.