

Recent advances in the MixAlco process for the production of mixed alcohol fuel

Frank K Agbogbo, Mark T Holtzapple

Department of Chemical Engineering

Texas A&M University

TX 77843-3122

Phone: 979-845-9708

E-mail: m-holtzapple@tamu.edu

Limited biomass disposal sites and stringent environmental regulations call for a technology to convert biomass wastes into useful products. Biomass comes from a variety of sources, such as industrial wastes, agricultural residues, forest residues, animal manure, municipal biosolids, and municipal solid wastes. The total biomass generated by the United States from industrial wastes, agricultural residues, forest residues, animal manure, municipal biosolids, and municipal solid wastes is 1,046 million tonne/year with an alcohol potential of 135 billion gal/year. The United States gasoline consumption is 130 billion gal/year; therefore, a major fraction of the United States energy needs can be supplied from the wastes generated.

An ideal biomass processing technology should be able to handle a variety of biodegradable feedstock. The MixAlco process can be used to convert any of these wastes into high-value fuels and chemicals, such as mixed alcohols, ketones, and mixed organic acids. The mixed alcohols can be used as oxygenates in gasoline and therefore reduce fossil fuel consumption. Moreover, using biomass for energy does not add new CO₂ to the atmosphere. The benefits of the MixAlco process include no sterility requirement, adaptability to a variety of feedstock, no pure cultures, low capital, no enzymes, no vitamins, and no co-products.

Through 14 years of development, the MixAlco process has advanced and improved the acid concentration, yield, and productivity. Improvements are detailed below:

1) The use of marine microorganisms instead of rumen or terrestrial microorganisms. Because osmotic stress is the ultimate barrier to achieving high acid concentrations, inocula from marine environments have salt-resistant bugs and strengthen the tolerance to high salt concentrations (Li, 2002). Inoculum from marine environments produced a higher product concentrations and conversions compared to inoculum from terrestrial and rumen ecosystem (Thanakoses *et al.*, 2003, Aiello-Mazzarri, 2002). The increases in product concentrations and conversions have reduced the cost of the mixed alcohols.

2) Improved biomass pretreatment that greatly improve biomass digestibility. Two types of lime treatment have been developed in our laboratory, short term and long term. Short-term lime pretreatment involves boiling the biomass with a lime loading of 0.1 g $\text{Ca}(\text{OH})_2/\text{g}$ dry biomass at temperatures of 85–135°C for 1–3 hours (Chang *et al.*, 1997, 1998). This removes approximately a third of the lignin and all the acetyl groups from hemicellulose (Chang *et al.*, 2000). Chang *et al.* (2001) showed that oxidative lime pretreatment could be used to pretreat high-lignin biomass. Long-term pretreatment involves using the same lime loading at lower temperatures (40–55°C) for 4–6 weeks in the presence of air. Kim (2004) showed that long-term pretreatment removes about half of the lignin and all the acetyl groups in corn stover. The improved pretreatment has been shown to double acid concentrations and conversions (Thanakoses, 2002).

3) Improved fermentors. In the traditional approach of the MixAlco process, pretreatment and fermentation are separate unit operations. It is possible to combine these unit operations into a single step in a pile where biomass can be stored and pretreated at the same time.

All these changes have made the technology very competitive. Economic estimates indicate that mixed alcohols can be sold for \$0.60 to \$0.80/gal with a 15% ROI (return on investment) at production capacities between 40 and 800 tonne/h.

References

- [1] Aiello-Mazzarri, C. 2002. Conversion of municipal solid waste to carboxylic acids by anaerobic countercurrent fermentation. PhD dissertation, Texas A&M University, College Station, Texas.
- [2] Chang, V.S., Burr, B., Holtzapple, M.T. (1997). Lime pretreatment of switchgrass. *Applied Biochemistry and Biotechnology*, **63-65**, 3-19.
- [3] Chang, V.S., Nagwani, M., Holtzapple, M.T. (1998). Lime pretreatment of crop residues baggasse and wheat straw. *Applied Biochemistry and Biotechnology*, **74**, 135-159.
- [4] Chang V.S., Holtzapple, M.T. (2000). Fundamental Factors Affecting Biomass Enzymatic Reactivity, *Applied Biochemistry and Biotechnology*, **84-86**, 1-37.
- [5] Chang, V.S., Nagwani, M., Kim, C.H., Holtzapple, M.T. (2001). Oxidative lime pretreatment of high-lignin biomass. *Applied Biochemistry and Biotechnology*, **94**, 1-28.
- [6] Kim, S. (2004). Lime pretreatment and enzymatic hydrolysis of Corn Stover. PhD dissertation, Texas A&M University, College Station, Texas.
- [7] Li, X. (2002). Production of acetic acid from synthesis gas with mixed acetogenic microorganisms. PhD dissertation, Texas A&M University, College Station, Texas.
- [8] Thanakoses, P. (2002). Conversion of baggasse and corn stover to mixed carboxylic acids using a mixed culture of mesophilic microorganisms. PhD dissertation, Texas A&M University, College Station, Texas.
- [9] Thanakoses, P., Mostafa, N.A.A., Holtzapple, M.T. (2003). Conversion of sugarcane bagasse to carboxylic acids using a mixed culture of mesophilic microorganisms. *Applied Biochemistry and Biotechnology*. **105**, 523-546.