Bioalcohol - a biorefinery approach

Liisa Viikari, University of Helsinki, Finland

Today, the greatest challenges of our society are related to the growing demand for energy and the urgent need to reduce greenhouse gas (GHG) emissions. Transportation fuels contribute to about 20% of the world use of energy. Bioethanol has been given a high priority as a transportation fuel worldwide, because it can provide an immediately applicable and sustainable alternative with reduced GHG emissions in comparison with oil based gasoline. In the EU, 5.75% of transportation fuel should be replaced by biocomponents by 2010 and 10% by 2020. Almost all current production of bioethanol is carried out with 1st generation technology using predominantly sugar cane or starch as raw material. The net energy gain and benefits in CO_2 emissions of grain derived biofuels remain, however, unsatisfactory. On the other hand, the calculated benefits of fuel ethanol produced from lignocellulosic materials or from sugar cane are much more beneficial. Furthermore, these raw materials would not compete with food production.

Lignocellulosic raw materials, such as corn stover, straw, sugar cane bagasse, dedicated energy crops, as well as forest residues, could thus be a reliable fuel source and gradually reduce the dependence on oil imports. Advanced conversion technologies are, however, needed to produce biofuels, such as ethanol or butanol, from lignocellulosic biomass. The major technological obstacles are in the enzymatic hydrolysis of lignocellulose into sugars, due to the recalcitrance and complex structure of the raw material itself, and in the fermentative conversion of sugars into ethanol or other energy carriers. During the last 10 years, significant improvements in bioconversion technologies have been achieved. This is mainly due to advances in improved pretreatment technologies and biosciences, which have led to decreased prices of cellulolytic enzymes and to more efficient organisms for fermentation. Of the various pretreatment options, hydrothermal pretreatments (incl. steam pre-treatment) have been most extensively studied and widely tested in pilot scale. Pretreatments disrupt the plant cell wall and improve the accessibility of enzymes to the polysaccharides. The capital and operating costs for lignocellulose pretreatment, such as steam explosion, are estimated to be about 20% of the total production costs of ethanol.

The high cost of cellulases is still considered a key barrier to economic production of 2nd generation ethanol. Despite the declared reductions in enzyme costs there is an obvious need for further development. Several approaches have been taken to improve the performance and to decrease the amount of enzymes needed to saccharify lignocellulosic substrates; improving individual cellulase components or complementing or replacing the set of cellulases by novel proteins. Lignin has been shown to bind cellulases and reduce their service life and therefore, reducing their non-specific binding to lignin is also a challenge. Thermostable enzymes offer potential benefits in the hydrolysis of lignocellulosic substrates; higher specific activity decreasing the amount of enzymes needed, enhanced stability allowing improved hydrolysis performance, better inhibitor tolerance and increased flexibility with respect to process configurations, all leading to improvement of the overall economy of the process. Considering the other major cost factors, significant development has been achieved in increasing the ethanol production efficiency by yeast and bacteria using tools of metabolic engineering.

Presently, numerous process concepts are being developed with variables in terms of raw materials, pretreatment technologies, hydrolysis methods and fermenting organisms. The general aim is to decrease the production costs of ethanol from second generation lignocellulosic biorefineries, simultaneously reaching a high conversion rate and yield of all available carbohydrates into ethanol. This papers discusses various approaches to improve the conversion efficiency of lignocellulosic raw materials into ethanol.