



The production of ethanol from lignocellulose-rich materials such as wood residues, waste paper, used cardboard and straw cannot yet be achieved at the same efficiency and cost as from corn starch. A cost comparison has concluded that using lignocellulose materials is unlikely to be competitive with starch until 2020 at the earliest. The study, published in the international journal *Biofuels, Bioproducts & Biorefining*, did identify many opportunities for reducing costs and improving income within the lignocellulose-to-ethanol process, and provides insight into the priority areas that must be addressed in coming years.

Ethanol can be blended with gasoline to reduce our dependency on fossil fuels. The last 15 years has seen a massive growth of so-called first-generation processes that use enzymes and bacteria to turn the starch and sugars in corn and sugarcane into ethanol. But corn and sugarcane are also important components of the human food web, so using them for ethanol production has the potential to affect the price and availability of these basic commodities.

On the other hand, lignocellulose materials are often hard to dispose of, but they are rich in sugars that can be fermented into ethanol following appropriate processing. "Not only is cellulose the most abundant polymer on Earth, it cannot be digested by humans, so using it for fuel production does not compete directly with food supplies," says the study's lead author Jamie Stephen, who works in the Department of Wood Science at the University of British

Columbia in Vancouver, Canada. The race is on to commercialize this second generation ethanol.

Stephen's work focuses on the fact that the cost of building large scale ethanol-producing facilities will likely be higher for second generation ethanol compared to first generation technologies. One reason is that sources of lignocellulose may require significant and costly pre-treatment. "Researchers and companies are going to have to concentrate on reducing the cost of pretreatment and increasing the output of the digester in order to reduce the costs of the lignocellulose-to-ethanol process," says Stephen.

Another reason costs are higher is that lignocellulose is made of multiple kinds of sugar, while corn starch consists of pure glucose. Corn starch can be reduced to glucose with low-cost amylase enzymes, while pre-treated lignocellulose requires a cocktail of cellulase enzymes. Providing these enzymes is one of the major costs of the whole process, but you currently need 12 times more cellulase than amylase protein to generate the same amount of ethanol from woody biomass. "Despite much effort and progress over the last few years, the cost of using cellulase enzymes is still significantly higher than for amylase-based processes, and will need to be reduced substantially before lignocellulose starts to become competitive with corn and sugarcane as a feedstock," says Stephen.

Finally, while the input to sugarcane- and corn starch-based systems is fairly constant, the feedstocks that go into lignocellulose systems are much more variable. Different species of tree produce wood that has different properties, and waste paper and agricultural wastes will have many different types of material in them. To get maximum efficiency, each type of biomass needs to be processed under different conditions, which introduces another challenge for anyone wanting to make ethanol from these materials.

Overall Stephen believes we have a considerable way to go before second-generation ethanol production will be ready for commercialisation. "Production requires significant cost reductions and at least the same level of financial support that was given to the first-generation systems if second-generation ethanol is going to be fully competitive by 2020," says Stephen.

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