Scientists hit the sweet spot on sugar conversion for biofuels

By Reeder Robinson

Lignocellulosic biomass has the potential to be used for biofuel production, but the abundance of lignin and hemicelluloses presents a hurdle as these types of sugars are difficult to convert into biofuels. A research team at the University of California, Berkeley led by Dr. Henrik Vibe Scheller is attempting to solve this problem through bioengineering plants so they grow with less of these sugars that are difficult to ferment.

In a 2012 study published in Biotechnology for Biofuels, Dr. Scheller's team demonstrated in the plant model organism Arabadopsis thaliana, that the genetic traits could be manipulated to produce more favorable sugars for biofuel production through a spatio-temporal bioengineering approach. They set out to improve the phenotypic properties of irregular xylem mutants in Arabadopsis, which show stunted growth, and are deficient in xylan and cannot transport water through their weakened vessels. Xylans are polysaccharides composed mainly of pentose sugars, which are not easily fermented like hexose sugars due to inefficient depolymerization of polysaccharides by enzymatic pretreatment. These xylan sugars are essential in plant cell walls for structural integrity, but are not essential in all cell types.

In this study, Dr. Scheller and his team used tissue-specific promoters to strengthen xylem vessels through directing xylan biosynthesis only in the xylem vessels which reduced overall xylan content in the plant. This approach allowed only the genes needed for xylan biosynthesis to be expressed in the cell wall, but not in other cell types in the plant. These bioengineered plants grew similarly to wild-type plants with large, open vessels for water transport, but the plants showed a 16-23% reduction in xylose content and a corresponding 46% increase in the ratio of hexose to pentose sugars. Furthermore, the stem strengths in the bioengineered plants were equivalent or better than wild-type plants. These bioengineering accomplishments also led to a boost in saccharification yields of 42-55% after pretreatment of the plant biomass.

"Mutants that are deficient in xylan grow poorly, but here we demonstrated a way to keep xylan content low while still maintaining good growth" says Dr. Scheller. Further, "We have a higher proportion of hexose sugars like glucose and less xylose which is difficult to convert into fuels." This highlights Dr. Scheller's overall strategy to maintain biomass in plants while simultaneously improving hexose saccharification yields.

Dr. Scheller envisions utilizing a similar bioengineering technique in other plants that are fast growing and have high biomass yields. "We are working with a couple of companies currently trying to implement this into other plants such as poplar, switchgrass, and eucalyptus which all have high biomass" he says. One potential obstacle Dr. Scheller sees though, "If you want to do this in a tree, you need to either have a mutant available that you can repair in the same way or knockdown the endogenous genes." He sees RNAi, a process where RNA inhibits gene expression, as a potential method of suppressing xylan biosynthesis if a mutant is not available for any of these species. "We are also currently trying to combine favorable traits together, such as low lignin and xylan content and high-density cell walls, into one plant to see if these traits can be added together, or if there is a problem doing everything at once," he says. If any of these strategies can be implemented in the future into a bioengineered tree for biofuel production, then it could present an economical alternative to current fossil fuels.

"A big hurdle for biofuel production is deconstructing the biomass into sugars which involves pretreatment with acids and addition of enzymes [to breakdown the complex carbohydrates] which adds a lot of cost to the process," says Dr. Scheller. On the other hand, current modeling data predict that cutting xylose by 20% and lignin by 10% could lower bioethanol prices by 10-15%, suggesting that his strategy and others could one day lead to economical biofuels that do not siphon off our food supply. ▼