Novel Combination of Enzyme Systems Could Lower Biofuel Costs

Highlights in Science

Two biomass-degrading enzyme systems that work in very different ways are shown to be more effective at releasing plant sugars when used together.

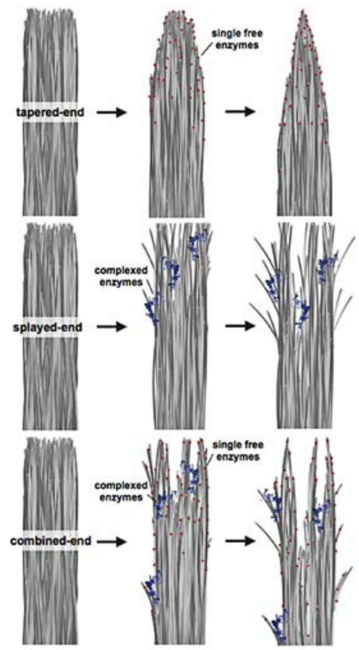

Illustration of the mechanisms by which free enzymes (top) and cellulosomes (middle) differ in their action on cellulose microfibril bundles and act synergistically to degrade cellulose (bottom). Image by Bryon Donohoe, NREL

Two natural enzyme systems—one produced by fungi and the other by bacteria—break down cellulose faster if used in combination. The resulting process shows promise for less expensive biofuels. Researchers from the National Renewable Energy Laboratory (NREL) and their partners studied a cocktail of individual fungal enzymes that depolymerize biomass, and an alternative bacterial system in which multiple biomass-degrading enzymes, termed the cellulosome, are linked together by a protein scaffold. This study suggests that two of the most thoroughly studied and distinct paradigms of biomass degradation, namely free fungal enzymes and multi-enzyme bacterial cellulosomes, function together in an unexpected way to efficiently break down polysaccharides.

A large barrier to reaching the goal of producing low-cost biofuels is the high cost of enzyme treatment, a crucial step in turning biomass—switchgrass, energy trees, corn stover, and the like—into liquid fuels. A number of enzymatic strategies are used to degrade polysaccharides in a plant cell wall into sugars for conversion to biofuels. Free enzymes are more active on pretreated biomass; in contrast, cellulosomes are much more active on purified cellulose. In this research, free enzymes and cellulosomes were compared. When the two enzyme systems were combined, cellulose was broken down to sugar faster and more efficiently than with either system alone. Physical changes to the substrate suggest synergistic deconstruction mechanisms.

Transmission electron microscopy revealed evidence that free enzymes and cellulosomes employ different physical mechanisms to degrade cellulose microfibrils. The individual fungal enzyme system demonstrates an "outside-in" degradation pattern where the biomass is broken down sequentially from the outer surface. The bacterial cellulosomal system shows evidence of "splitting" the cellulose into smaller pieces by hydrolyzing down the middle of the cellulose macrofibril. When combined, these systems display dramatic synergistic enzyme activity on cellulose, hinting at a means for faster and more efficient conversion of biomass, which would lead to lower costs for biomass-derived renewable fuels.

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Reference: Resch; M.G.; Donohoe, B.S.; Baker, J.O.; Decker, S.R.; Bayer, E.A.; Beckham, G.T.; Himmel, M.E. (2013). "Fungal Cellulases and Complexed Cellulosomal Enzymes Exhibit Synergistic Mechanisms in Cellulose Deconstruction," *Energy & Environmental Science* (6); pp. 1858–1867.

Key Research Results

Achievement

Researchers have demonstrated that mixing disparate enzyme systems can break down cellulose more rapidly and efficiently than either system alone.

Key Result

Although free cellulases and cellulosomes employ very different physical mechanisms to break down recalcitrant polysaccharides, when combined these systems display dramatic synergistic enzyme activity on cellulose.

Potential Impact

This study indicates new opportunities for mixing free enzymes and cellulosomes in an industrial setting, with the potential for an optimal synergy between two natural mechanisms for biomass deconstruction that further enables cost-effective biofuels production.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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