Study finds synergy in two approaches to breaking down cell walls of biomass

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Enzymes could break down cell walls faster – leading to less expensive biofuels for transportation – if two enzyme systems are brought together in an industrial setting, new research by the Energy Department's National Renewable Energy Laboratory suggests.

A paper on the breakthrough, "Fungal Cellulases and Complexed Cellulosomal Enzymes Exhibit Synergistic Mechanisms in Cellulose Deconstruction," appears in the current edition of *Energy and Environmental Science*. Co-authors include five scientists from NREL and one from the Weizmann Institute in Israel.

The Energy Independence and Security Act of 2007 has set a goal of producing 36 billion gallons of biofuel a year in the United States by 2022, including 21 billion gallons coming from advanced biofuel production. One barrier to reaching that goal is the high cost of enzyme treatment, a crucial step in turning the biomass – poplar trees, switchgrass, corn stover, and the like – into liquid fuel.

Enzymes secreted by microorganisms naturally degrade the cell walls of plants, breaking them down so their sugars can be harvested. But plants have their own survival tricks, including mechanisms to make it harder for the enzymes to break down the cell walls. Those defenses boost the cost of producing biofuels, and have pushed researchers to try to find combinations of enzymes that can do the job faster.

NREL researchers found that two enzyme paradigms – free and complexed enzymes – use dramatically different mechanisms to degrade biomass at the nanometer scale. Further, they found that mixing the two systems enhances catalytic performance. The findings suggest that there may be an optimal strategy between the two mechanisms – one that Nature may already have worked out.

When the two enzyme systems are combined, the substrate changes in unexpected ways and that result suggests the two systems work with each other to deconstruct the cell walls more efficiently. Scientists can use this knowledge to engineer optimal enzyme formulations – fast, efficient, single-minded and hungry.

To outmaneuver the plant's survival mechanisms, many microorganisms secrete synergistic cocktails of individual enzymes, with one or several catalytic domains per enzyme. Conversely, some bacteria synthesize large multi-enzyme complexes, called cellulosomes, which contain multiple catalytic units per complex.

While both systems use similar catalytic chemistries, the ways they degrade polysaccharides has been unclear.

NREL researchers found that the free enzymes are more active on pretreated biomass, while the cellulosomes are more active on purified cellulose. Using electron microscopes they found that free enzymes attack the plant cell wall surface by chipping and eroding, helped along by sharpening the thread-like cellulose fibers.

By contrast, the cellulosomes physically separate individual cellulose microfibrils from larger particles to enhance access to the cellulose surfaces. They assemble protein scaffolding to help get the job done.

NREL researchers observed that when the two enzyme systems are combined, the work improves dramatically, likely due to our combining enzymes that evolved naturally, and independently, to do the same job in different ways.

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