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“Biomass Recalcitrance: The Road to 2012”

Lignocellulosic biomass has long been recognized as a potential sustainable source of mixed sugars for fermentation to biofuels and other biomaterials. Several technologies have been developed over the past 80 years that allow this conversion process to occur, yet the clear objective now is to make this process cost-competitive in today's markets. Our work investigates the natural resistance of plant cell walls to microbial and enzymatic deconstruction collectively known as “biomass recalcitrance.” It is this property of plants that is largely responsible for the high cost of lignocellulose conversion.

Plant biomass has evolved complex structural and chemical mechanisms for resisting assault on its structural sugars from the microbial and animal kingdoms. Natural factors believed to contribute to the recalcitrance of lignocellulosic feedstock to chemicals or enzymes include the: 1) epidermal tissue of the plant body, i.e., cuticle and epicuticular waxes, 2) arrangement and density of the vascular bundles, 3) relative amount of sclerenchymatous (thick wall) tissue, 4) degree of lignification, 5) structural heterogeneity and complexity of cell wall constituents, i.e., microfibrils and matrix polymers, 6) challenges for enzymes acting on an insoluble substrate, and 7) inhibitors to subsequent fermentations that exist naturally in cell walls or are generated during conversion processes. In the context of the biorefinery, these chemical/structural features of biomass affect liquid penetration and/or enzyme accessibility/activity and thus conversion costs.

Crystalline cellulose is hydrolyzed by the synergistic action of endo-acting, (with respect to the cellulose chain) known as endoglucanases, and exo-acting enzymes, known as exoglucanases. The endoglucanases locate surface sites at locations, probably found at random along the cellodextrin and insert a water molecule in the beta (1,4) bond, creating a new reducing and non

reducing chain end pair. Computer simulations of such newly created chain ends demonstrate that water molecules soon invade the space under the non reducing chain end and thus prevent it from re-annealing into the cellulose crystal. The removal of cellodextrins from the microfibril core is thought to occur at these new chain ends and this process, considered to be the rate limiting step in cellulase action, is accomplished by exoglucanases also known as the “processive” cellulases. For a cost effective biomass to fuels process to be commercialized, the cost of enzymatic processing of feedstocks must be reduced about 5-fold (to about \$0.12 per gallon ethanol produced).