Trend

Cellulose Degradation, a World in Which Oxidoreductase Enzymes Assist Hydrolase Enzymes

Author

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[Brief background]

Igarashi became a research assistant at the Graduate School of Agricultural and Life Sciences at the University of Tokyo in 2002, an assistant professor in 2007, an associate professor in 2009, and has been in his current position since 2021. Since 2016, he has also worked as a visiting professor at the VTT Technical Research Centre of Finland Ltd., Finland. He is a leader in research on producing energy and materials from trees and grasses. He has served on numerous committees, including review committees for major projects, promotion committees, and evaluation committees for the Ministry of the Environment, the Ministry of Agriculture, Forestry and Fisheries, the Cabinet Office of Japan, and others.

Although studies on enzymatic cellulose degradation have been conducted since the late 19th century, the mechanistic research was first reported by Reese et al. in 1950[1]. Reese et al. proposed the "C_1-C_x theory," in which cellulose is first hydrated by a component called C_1, and then the hydrated cellulose is hydrolyzed by an enzyme called the C_x component. However, in the 20 years following the report, the enzyme corresponding to the C_1 component was never discovered. As a result, the Endo-Exo theory, in which Endo-type enzymes degrade amorphous cellulose then subsequently Exo-type cellulases degrade cellulose from the ends came to be widely accepted. However, in the 1970's, a paper by Eriksson et al. found that cellulose degradation would advance faster with oxygen and proposed the theory of the "oxidative boost."[2] In the 21st century, the enzymes "lytic polysaccharide monooxygenases (LPMOs)" were discovered to be the reason for this. LPMO contains copper atoms, which could be used to oxidatively split the surface of crystalline cellulose and cause other enzymes to react. We have recently shown through high-speed atomic force microscopy that LPMO (AA9D) produced by *Phanerochaete chrysosporium*, a type of wood-rotting fungi, increases the activity of other hydrolytic enzymes while producing only a small amount of the oxidized oligosaccharides, and increases the number of hydrolytic enzyme molecules moving on the cellulose surface.[3] This finding proves that the three previously discussed theories, C_1-C_x, Endo-Exo, and oxidative boost, are simply different ways of looking at the same phenomenon, ending a 70-year debate. Considering the efficiency of cellulose degradation that such organisms can conduct in nature, it is thought to be possible to make cellulose degradation more efficient. Increased efficiency of cellulose degradation is expected to lead to effective use of biomass. Learning from nature will be important for human beings in its endeavor to achieve a sustainable circular society.

Comic strip showing cellulose degradation by enzymes (© Natsumi Furuyama)

References

1) Reese *et al.* ***J. Bacteriol.*** 59(4), 485–497 (1950)
2) Eriksson *et al.* ***FEBS Lett.*** 49(2), 282-285 (1974)
3) Uchiyama *et al.* ***Science Adv.*** 8, eade5155 (2022)