148. The Passalid Beetle (Odontotaenius disjunctus) Microbiome and its Metabolic Potential for Lignocellulose Degradation

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https://envmicro.wordpress.com/researchprojects/passalid-beetles-natures-efficient-lignocellulosic-biorefineries/

Project Goals: Our research aims to develop an integrated analysis of energy flow in complex microbial communities by combining multi-scale approaches including biogeochemical, stable isotope probing, metagenomic/transcriptomic, proteomic and computational analyses, to understand nutrient cycling and biofuel production in complex microbial communities. A comprehensive understanding of such communities may help in the development of efficient, industrial-scale processes for lignocellulose degradation. Our ultimate goal is the development of multi-scale models that can predict ecological and biochemical relationships within multi- trophic microbial systems.

Insects are the most abundant group of metazoans on Earth and have evolved to exploit a diverse array of environments, an ability that may be facilitated and enhanced by their gut-associated microbes. The wood-feeding beetle Odontoatenius disjunctus displays morphologically differentiated gut regions where stratified microbial communities degrade lignocellulosic materials and fix nitrogen. Our goal is to characterize the genomic potential stored in the microbiome of the passalid beetle for the optimization of lignocellulosic-dependent energy production processes.

Metagenomes were prepared from four gut regions of replicate beetles, sequenced, co- assembled and annotated. The ability to transform lignocellulosic materials by the passalid beetle was tested by Fourier Transform Infrared Spectroscopy and by measuring the fermentation products of plant polymer decomposition (H2 and CH4) with gas chromatography-isotope ratio mass spectrometry (GC-IRMS). The transformation of lignin after its passage through the gut was determined by 13C-labeled tetramethylammonium hydroxide thermochemolysis. Proteomics and metabolomics were applied to detect expressed proteins and produced metabolites in each gut region.

After passage through beetles, oak wood showed cellulose and hemicellulose hydrolysis and lignin side chain oxidation. C and H stable isotope fractionation indicated that hydrogenotrophic methanogenesis dominates methane production the in beetle. These processes are mediated by a diverse range of bacteria, archaea and fungi in the metagenomes. Cellulose, starch, and xylan degradation genes were particularly abundant in the midgut (MG) and posterior hindgut (PHG). Genes involved in hydrogenotrophic production of methane and nitrogen cycling were more abundant in the anterior hindgut, confirming our previous phylogenetic and nitrogen fixing studies of compartmentalization in the passalid beetle gut1. A filtered isolate database and predicted protein sequences from the metagenomes were used to search peptide spectra for proteome reconstruction. Proteomics supported metagenome observations, detecting expression of carbohydrate active enzymes principally in the MG and PHG, and nitrogenases and the enzymes involved in methane production in the AHG. Co-assembly and binning identified linked functions within microbial genomes including organisms with cellulosomes and a combined potential for cellulose, xylan and starch binding and hydrolysis.

Our multi-scale approach demonstrates that the passalid beetle harbors and expresses the functional potential to deconstruct lignocellulosic materials and produce H2, CH4 and potentially other biofuels. By studying such highly spatially and biochemically evolved polymer deconstruction and fermentation systems we hope to identify design criteria for improved lignocellulosic fuel production processes.

References

1. Ceja-Navarro, J. A. et al. Compartmentalized microbial composition, oxygen gradients and nitrogen fixation in the gut of Odontotaenius disjunctus. ISME J. 8, 6–18 (2014).

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