

Linking temperature sensitivity of decomposition with substrate quality and microbial physiology

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Carbon dioxide production via microbial degradation of organic matter (OM) may significantly accelerate anticipated global warming depending on its temperature sensitivity. Thus the controls on the degradation temperature sensitivity have been a topic of scientific debate in both terrestrial and marine systems. A leading hypothesis in the terrestrial literature (called enzyme kinetic or carbon quality hypothesis) suggests that the degradation of low-quality substrate (SOM with complex molecular structure) is more temperature sensitive than that of high-quality, simple substrate in accord with Arrhenius kinetic theory. Supporting evidence, however, relies largely on respiration-based indices of substrate quality. Furthermore, the enzyme-substrate reactions that drive SOM degradation may be regulated by microbial physiology (e.g., direct temperature effect on microbial community) and/or constrained by protective effects of soil architecture (e.g., micro-aggregate formation via organo-mineral interaction).

We thus tested the kinetic hypothesis by directly assessing the carbon molecular structure of low-density fraction (LF) which represents readily accessible, mineral-free SOM pool. Using five mineral soil samples of contrasting SOM concentrations, we conducted 30-days incubations (15, 25, and 35 °C) to measure microbial respiration and quantified easily-soluble C as well as microbial biomass C pools before and after the incubations. The respiration Q₁₀ was significantly correlated with the abundance of aromatic plus alkyl-C relative to O-alkyl-C groups in LF but not in bulk soil fraction or with the indirect C quality indices based on microbial respiration or biomass. The laboratory warming did not significantly change the size of microbial biomass C or the three types of soluble C pools despite two- to three-fold increase in respiration. These results suggest that the enhanced microbial maintenance respiration (reduced C-use efficiency) upon warming especially in the soils rich in recalcitrant LF might lead to the apparent equilibrium between SOM solubilization and microbial C uptake. Our results showed physical fractionation coupled with direct assessment of molecular structure as an effective approach and supported the enzyme-kinetic interpretation of widely observed C quality-temperature relationship for short-term degradation. Factors controlling the Q₁₀ of long-term SOM degradation are more complex due to protective effect of mineral matrix and thus remain as a central question.

Keywords: soil organic matter, microbial degradation, NMR, density fractionation, kinetic theory, Q₁₀