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Hot experience for cold-adapted microorganisms: temperature sensitivity of soil enzymes

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The temperature sensitivity of enzymes responsible for organic matter decomposition in cold environment soil, where warming is expected to be greatest is crucial. Based on Michaelis-Menten kinetics and Arrhenius function, we hypothesized that cold-adapted microorganisms will produce high efficient enzymes at cold temperatures (enzymes with lower apparent activation energy (Ea) at cold temperature ranges).
To test our hypothesis, 30 g soil of Tibetan Plateau (4100 m a.s.l., annual temperature 2.4 °C) in 4 replicates were incubated for one month over a temperature range of 0–40 °C (with 5 °C steps) and determined the kinetic parameters of six enzymes involved in decomposing organics: cellobiohydrolase and β-glucosidase, which are commonly measured as enzymes responsible for consecutive stages of cellulose degradation; xylanase, which is responsible for breaking down hemicelluloses; acid phosphatase, which mineralizes organic P to phosphate by hydrolyzing phosphoric (mono) ester bonds under acidic conditions. Activities of leucine aminopeptidase and tyrosine aminopeptidase were analyzed to assess the hydrolysis of L-peptide bonds.
The apparent activation energy varied between enzymes from 42 (phosphatase) to 54 (cellobiohydrolase) kJ mol-1 corresponding to the Q10 values of the enzyme reactions of 1.8–2.3. The increase of substrate affinity (Km) with temperature was gradual for most tested enzymes from 0–20 °C (enzymes involved in C cycle), (proteases) and 0–40 °C (phosphatase). However, within a high range of temperatures (25–40 °C) the hydrolytic activity was governed by enzymes with nearly constant substrate affinity.
Overall, for enzymes involved in C cycle and proteases, a strong increase (30–40%) in Km at high temperatures (25 °C) reflects an expression of multiple isoenzymes each with different temperature optima and probable shift of microbial community. The general trend of catalytic efficiency (Vmax/Km) demonstrated a gradual increase with temperature both at cold and at warm ranges. The only remarkable exception occurred at 25 °C, where a strong increase in Km was accompanied by a significant decrease in catalytic efficiency. In agreement with our hypothesis, high catalytic efficiency was accompanied by low Ea at cold temperature ranges. We conclude that predicting and modeling the consequences of warming for C, N and P cycles should consider possible temperature thresholds triggering strong changes in catalytic efficiency and, thus, in the process rates.

Keywords: Tibetan plateau, cold-adapted enzymes, Arrhenius function, Michaelis-Menten kinetics, catalytic efficiency, temperature sensitivity.