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Thermodynamics of propionate degradation in methanogenic paddy soil

Nailia I. Krylova¹, Ralf Conrad **Max-Planck-Institut für terrestrische Mikrobiologie, Karl-von-Frisch-Str., D-35043 Marburg, Germany*

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Abstract

Propionate is syntrophically degraded in methanogenic paddy soil via a randomizing pathway. To study the thermodynamic conditions of this syntrophy, propionate degradation was measured in the presence of different H₂ partial pressures (1–20 000 Pa) using methanogenic soil slurries taken from planted Italian paddy soil. The logarithmic decrease of [1-¹⁴C]propionate or [2-¹⁴C]propionate was measured during an incubation period of about 2–3 h to determine degradation rate constants (*k*). The change of the H₂ partial pressure was measured during the same period. Values of *k* decreased with increasing H₂ partial pressures (averaged over the incubation period). However, *k* was still relatively high, although the Gibbs free energy (ΔG) of syntrophic propionate conversion to acetate, bicarbonate and H₂ was already strongly endergonic reaching ΔG values of +60 kJ mol⁻¹ propionate. Assuming propionate conversion to acetate plus formate resulted in the same or even higher ΔG values indicating that this degradation pathway was not realistic. We therefore assume that propionate was degraded within microbial aggregates in which syntrophic propionate degraders were shielded from thermodynamically unfavorable H₂ by methanogenic bacteria consuming H₂. Gibbs free energies for H₂ formation from propionate correlated negatively with the ΔG values for H₂ conversion to CH₄, but the latter values were generally < -5 kJ mol⁻¹ H₂ so that methanogenesis from H₂ was always possible. Addition of sulfate did not result in a significant decrease of the ΔG values for H₂ formation from propionate demonstrating that H₂ consumption by sulfate reducers was not relevant during the short incubation period. Nevertheless, propionate degradation was less strongly inhibited by H₂ when sulfate was present indicating that propionate was then mainly degraded by sulfate reduction rather than by syntrophy. The major degradation product of [2-¹⁴C]propionate was ¹⁴C-acetate (followed by ¹⁴CO₂ and ¹⁴CH₄) showing that the sulfate reducers oxidized propionate primarily to acetate, bicarbonate and H₂. As a conceptual model we therefore speculate that propionate was degraded within methanogenic bacterial aggregates both in the presence and the absence of sulfate and that propionate degraders operated either as sulfate reducers or as H₂-producing syntrophs. © 1998 Federation of European Microbiological Societies. Published by Elsevier Science B.V. All rights reserved.

Keywords: Methanogenesis; Sulfate reduction; Gibbs free energy; Syntrophy; Hydrogen; Formate; Microbial aggregate

* Corresponding author.

Tel.: +49 (6421) 178 801; Fax: +49 (6421) 178 809;
E-mail: conrad@mail.uni-marburg.de

¹ Present address: Microbiology Department, Kazan State University, Lenin Str. 18, Kazan 420008, Tatarstan, Russia.

1. Introduction

Propionate is an important intermediate in the anaerobic degradation of organic matter to CH₄ and is detected in a large variety of anoxic environ-