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Turnover of propionate in methanogenic paddy soil

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Abstract

Samples from planted Italian paddy soil exhibited most probable numbers (MPN) of about 10^7 anaerobic propionate utilizers. In anoxic soil slurries that were either unamended or amended with rice straw production of CH_4 was measured together with concentrations of H_2 , acetate and propionate. After a lag phase, during which ferric iron was depleted, CH_4 was produced at a constant rate which was slightly higher in the straw-amended than in the unamended soil. Propionate concentrations were relatively low at about 5–15 μM . However, in the straw-amended soil propionate transiently accumulated to about 35 μM just after onset of methanogenesis. During the period of propionate accumulation H_2 partial pressures were elevated and the Gibbs free energy (ΔG) of propionate consumption to acetate, bicarbonate and H_2 was endergonic or higher than -3 kJ mol^{-1} propionate. Propionate concentrations decreased again when the ΔG decreased to more negative values. In unamended paddy soil, propionate did not accumulate transiently and ΔG was always $< -6 \text{ kJ mol}^{-1}$ propionate. Propionate radiolabelled in the C-1 or C-2 position was utilized with turnover times of 30–60 min. Propionate turnover rates approximately accounted for the rates of H_2/CO_2 -dependent methanogenesis that were measured in experiments with [^{14}C]bicarbonate. The only radioactive product of [$1\text{-}^{14}\text{C}$]propionate was $^{14}\text{CO}_2$. However, [$2\text{-}^{14}\text{C}$]propionate was converted to radioactive acetate, CO_2 and CH_4 . This observation indicates that propionate was consumed via a randomizing pathway to CO_2 and acetate, the latter being then further degraded by acetotrophic methanogens to CO_2 and CH_4 . Turnover of [$1\text{-}^{14}\text{C}$]propionate was almost completely inhibited by high H_2 concentrations, chloroform or molybdate. The MPN of bacteria that utilized propionate either in syntrophy with methanogens or by reduction of sulfate was identical. All these observations suggest that propionate was consumed by a syntrophic randomizing pathway, probably by bacteria that have also the capacity to reduce sulfate.

Keywords: Methanogenesis; Propionate degradation pathway; Gibbs free energy; Syntrophy; Hydrogen; Acetate; Iron

1. Introduction

Projected global human population levels indicate that the demand for rice as food will increase from 460 to 760 Tg year⁻¹ by the year 2020 [1]. This growing demand can only be met by intensified rice production and will most likely increase the production and emission of CH_4 from the wetland rice fields if current agricultural management technolo-

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