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Competition for hydrogen in the rumen

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Methane emission (l/h) is greatest soon after feeding (Johnson et al, 1994, Environ Sci Technol, 28, 359-362) when the partial pressure of hydrogen in the rumen is highest (Smolenski and Robinson, 1988, FEMS Microbiol Ecol, 53, 95-100) and the rate of fermentation is greatest. For hydrogenotrophic mesophilic anaerobes there is an inverse relationship between the hydrogen partial pressure below which the organism can no longer use hydrogen and the free energy available for the reaction ($\Delta G°'$) (Cord-Ruwisch et al, 1988, Arch Microbiol, 149, 350-357). For reduction of CO_2 to CH_4, SO_4^{2-} to H_2S, and Fe^{3+} to Fe^{2+} respectively $\Delta G°'$ (kJ/mol H_2) is -33.9, -38.9 and -228.5. In a methanogenic river sediment the partial pressure of hydrogen was 0.82 Pa and it was reduced to 0.17 Pa with addition of SO_4^{2-} and to 0.03 Pa with addition of Fe^{3+} (Lovley and Phillips 1987, Appl Environ Microbiol, 53, 2636-2641). Hydrogen produced in the rumen is used in a variety reactions, including production of microbial biomass, propionate, butyrate and methane. In this study the effect on fermentation in the rumen of competition for hydrogen was determined by increasing dietary Fe^{3+}.

Twenty four sheep were fitted with permanent cannulae in the rumen and abomasum. To a diet of wheaten hay, lupin seed, supplementary minerals (with S supplied as SO_4^{2-}), and urea (0.82, 0.10, 0.06, 0.02) was added either 0, 50, 500 or 2000 mg $FeCl_3$/Kg DM. The ration (800g/d) was offered once daily for 35 days, and then in eight equal portions daily for 14 days. In this 14-day period ^{51}Cr-EDTA and ^{103}Ru-phenanthroline were used as digesta markers, faeces and urine, and samples of rumen and abomasal were collected, and CH_4 (%) in the rumen gasses was determined.

Increasing dietary intake of iron (FeI, mmol/d) depressed dry matter intake (DMI, g/d) ($p < 0.006$) and dietary intake of S (SI, mmol/d) ($p < 0.001$). When SI was used as a covariate in analysis of variance the effect of increasing FeI was to increase digestible organic matter intake (DOMI) ($p < 0.001$) and the molar proportion of butyrate in the rumen volatile fatty acids (Bu, %) ($p < 0.013$), and to depress the molar proportion of long-chain and branched-chain volatile fatty acids (LCVFA, %) ($p < 0.04$).

Synthesis of microbial biomass was expressed as non-ammonia-nitrogen flow from the rumen (NAN, g/d), the rate of fermentation as organic matter apparently fermented in the rumen (OMAFR, g/d) and the pattern of production of volatile fatty acids as the ratio of concentration of acetate to the sum of the concentrations of propionate, butyrate and LCVFA (PVFA). The relationship NAN = 2.5 log (SI:FeI) + 0.05 DMI - 0.14 OMAFR + 14.3 PVFA + 0.24 CH_4 + 1.0 Bu - 62 accounted for 78% of the variation in NAN flow (RSD = 2.99; $p < 0.001$). The coefficient of the effect of the ratio of SI to FeI was higher than that of the effect of CH_4 on NAN flow, suggesting that in the rumen methanogenesis has a higher hydrogen threshold than does reduction of SO_4^{2-} and Fe^{3+}. Whereas decreasing FeI or increasing SI were associated with greater synthesis of microbial biomass, the efficiency of synthesis of microbial biomass (NAN/OMAFR) was depressed by competition for hydrogen among reduction of SO_4^{2-} and Fe^{3+} and production of methane.

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