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Effect of rare earth elements on *in vitro* rumen microbial fermentation and feed digestion☆

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Abstract

The objectives of this study were to investigate the effects of rare earth elements (REEs) on *in vitro* rumen fermentation, gas production, microbial protein synthesis and nutrient digestion using *in vitro* batch culture and continuous culture technique. A mixture of REE containing (g/kg) 380 g of $LaCl_3 \cdot 6H_2O$, 521 g of $CeCl_3 \cdot 6H_2O$, 30 g of $PrCl_3 \cdot 6H_2O$ and 69 g chlorides of other light REEs. The experimental diet consisted of 885 g/kg barley grain, 84 g/kg barley silage and 31 g/kg supplement (dry matter (DM) basis). Diet supplemented with different dosages of REE (control, no additional REE; low, 400 mg/kg REE; and high, 800 mg/kg REE, DM basis) were incubated for 4, 8, 14 and 24 h in diluted rumen fluid. At the end of 24 h of incubation, gas production and concentration of volatile fatty acid (VFA) linearly increased with increasing REE supplementation; whereas, influence of REE supplementation on VFA profile was marginal. Dry matter disappearance was not affected ($P>0.10$). Six dual-flow continuous culture fermenters were used in a replicated 3×3 Latin square with same treatments and same diet used in the batch culture. Mean ruminal pH (5.71) and total VFA (93.6 mM) concentration were not affected by supplementation of REE. The molar proportion (mol/100 mol) of acetate (39.1) and propionate (50.5) was similar among the treatments. However,

Abbreviations: ADF, acid detergent fibre; BCFA, branch-chained fatty acid; CC, continuous culture; CP, crude protein; DM, dry matter; N, nitrogen; aNDF, neutral detergent fibre with amylase and sodium sulfite used in the NDF procedure; OM, organic matter; REEs, rare earth elements; VFAs, volatile fatty acids.

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the proportion (mol/100 mol) of butyrate was higher with the high REE (6.6) than with low REE (5.3) or the control (5.8). Ruminal true digestibilities of organic matter (OM) (0.785, 0.811 and 0.828), acid detergent fibre (0.360, 0.431 and 0.432) and crude protein (0.496, 0.590 and 0.589) for control, low and high REE, respectively, linearly increased with increasing REE supplementation, whereas, the increase in ruminal digestibility from low to high dosage of REE was minimal. Microbial nitrogen (N) production (g/day) and microbial efficiency (g N/kg of truly fermented OM) were not affected by treatments. Improvement of ruminal digestibility of OM due to REE supplementation was attributed to the increase in digestibility of fibre and degradability of protein. The results suggest that REE supplementation improved ruminal fibrolytic and proteolytic activities.

Keywords: Rare earth elements; Rumen fermentation; Digestibility; *In vitro* culture

1. Introduction

In recent years, there has been increasing public pressure to reduce the use of in-feed antibiotics, growth promoters and chemical additives in livestock production. This concern is due to the emergence of antibiotic resistant bacteria and the risk of chemical residues in food. However, the feed additives that enhance animal performance are highly needed in livestock production. Therefore, scientists have recently become interested in finding alternative technologies to promote efficient feed utilization in ruminants and improve animal productivity while reducing the need for in-feed antibiotics and chemical additives.

Rare earth elements (REEs) including La, Ce and other lanthanides are a group of elements with many similarities in chemical and biochemical characters. In China, REEs have been used as feed additives in animal production for more than 20 years. Numerous reports from the Chinese scientific community indicate that a small amount of REE mixtures in the diet increase not only the liveweight gain of pigs, cattle, sheep and chickens but also milk and egg production (Xiong, 1995; Wang and Xu, 2003). Liu et al. (in press) reported that total digestibility of diet was linearly increased with increasing level of La from 0, 450 to 900 mg, and then declined with 1800 mg per steer per day of La supplementation. Recently, the REEs have been shown, in Europe, improved growth performance of pigs, poultry and calves (He et al., 2001; Halle et al., 2003).

Several possible mechanisms have been suggested to explain the effects of REE addition on enhancing animal performance. Rambeck and Wehr (2005) suggested that REE, similar to in-feed antibiotics, promotes animal growth by influencing the development of bacterial species within the gastrointestinal tract through selectively inhibiting undesired bacteria. The REE may cause bacterial flocculation by changing the structure and altering the surface charge of bacterial membranes (Liu et al., 2004). Effects of enhancing animal performance may be related to improvements in nutrient digestibility and availability. A number of studies from the Chinese scientific community attributed the effects of REE to improved digestibility and utilization of nutrients (Lu and Yang, 1996; Xu et al., 1998).

We hypothesize that supplementation of REE may selectively affect microbial species in the rumen, and thus affect rumen fermentation and feed digestibility. The objective of this study was to investigate the effects of a mixture of REE supplementation on ruminal