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Effect of lauric acid and coconut oil on ruminal fermentation, digestion, ammonia losses from manure, and milk fatty acid composition in lactating cows

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ABSTRACT

This experiment (replicated 3 × 3 Latin square design) was conducted to investigate the effects of lauric acid (LA) or coconut oil (CO) on ruminal fermentation, nutrient digestibility, ammonia losses from manure, and milk fatty acid (FA) composition in lactating cows. Treatments consisted of intraruminal doses of 240 g of stearic acid/d (SA; control), 240 g of LA/d, or 530 g of CO/d administered once daily, before feeding. Between periods, cows were inoculated with ruminal contents from donor cows and allowed a 7-d recovery period. Treatment did not affect dry matter intake, milk yield, or milk composition. Ruminal pH was slightly increased by CO compared with the other treatments, whereas LA and CO decreased ruminal ammonia concentration compared with SA. Both LA and CO decreased protozoal counts by 80% or more compared with SA. Methane production rate in the rumen was reduced by CO compared with LA and SA, with no differences between LA and SA. Treatments had no effect on total tract apparent dry matter, organic matter, N, and neutral detergent fiber digestibility coefficients or on cumulative (15 d) in vitro ammonia losses from manure. Compared with SA, LA and CO increased milk fat 12:0, *cis*-9 12:1, and *trans*-9 12:1 content and decreased 6:0, 8:0, 10:0, *cis*-9 10:1, 16:0, 18:0, *cis* 18:1, total 18:2, 18:3 n-3 and total polyunsaturated FA concentrations. Administration of LA and 14:0 (as CO) in the rumen were apparently transferred into milk fat with a mean efficiency of 18 and 15%, respectively. In conclusion, current data confirmed that LA and CO exhibit strong antiprotozoal activity when dosed intraruminally, an effect that is accompanied by decreases in ammonia concentration and, for CO, lowered methane production. Administration of LA and CO in the rumen also altered milk FA composition.

Key words: lauric acid, myristic acid, coconut oil, protozoa

INTRODUCTION

Dietary fats are potent modifiers of ruminal fermentation and may offer a nutritional strategy to reduce protozoal predation and intraruminal recycling of bacterial protein, thus improving the efficiency of dietary protein utilization and mitigating N losses in the ruminant animal (Hristov and Jouany, 2005). Long-chain unsaturated fatty acids (**FA**) typically suppress the activity of fibrolytic bacteria in the rumen (Palmquist and Jenkins, 1980). Metabolism of C18 FA has been extensively investigated because of the interest in enhancing the concentrations of bioactive lipids in milk with the potential to improve long-term human health, including *cis*-9, *trans*-11 conjugated linoleic acid (**CLA**), *cis*-9 18:1, and 18:3 n-3 (Jenkins and McGuire, 2006; Shingfield et al., 2008c). Medium-chain saturated FA (**MCFA**) are also known to modify ruminal fermentation (Blaxter and Czerkawski, 1966; Henderson, 1973), effects that are of increasing interest with regards to mitigating greenhouse gas emissions from ruminant livestock production (Machmüller, 2006). Medium-chain FA such as lauric (**LA**) and myristic (**MA**) acids exhibit potent antiprotozoal properties and, by association, have an array of effects on formation of fermentation end products and methane production in the rumen (Sutton et al., 1983; Hristov et al., 2004a,b; Soliva et al., 2004). Suppression of ruminal methane production by LA, MA, or coconut oil (**CO**) as a source of these MCFA (CO contains 45% LA and 18% MA; CRC, 1988) is known to be mediated via a reduction in ruminal protozoal numbers and also through direct

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inhibition of rumen methanogens (Dohme et al., 1999, 2001). Thus, supplementation of cattle diets with MCFA or CO (as a source of LA and MA) may be a practically feasible method of reducing enteric methane emission from ruminants and the environmental impact of livestock operations. Reductions in ruminal ammonia concentration in response to LA (Machmüller et al., 2002; Hristov et al., 2004a) or CO (Dohme et al., 1999) may also reflect reduced proteolysis and deamination or more efficient conversion of ruminal ammonia into microbial protein, leading to an overall improvement in the efficiency of dietary N utilization. Because urinary urea is the primary source of ammonia emitted from cattle manure (Bussink and Oenema, 1998), formulation of diets that decrease urinary urea excretion are also central to nutritional strategies for the mitigation of ammonia emissions from manure.

Inclusion of LA (or CO) in the diet of dairy cows may also increase LA and MA content of milk fat (Steele and Moore, 1968; Rindsig and Schultz, 1974; Dohme et al., 2004). Clinical and epidemiological studies have provided evidence that when consumed in excess, LA, MA, and 16:0 in the human diet increase cardiovascular disease (**CVD**) risk and may also reduce insulin sensitivity which is a key factor in the development of the metabolic syndrome (Shingfield et al., 2008c). However, even though the constituent MCFA in CO may increase total plasma cholesterol, a high proportion of this is caused by elevated high-density lipoprotein (**HDL**) cholesterol concentrations. A meta-analysis of 60 human subject trials concluded that LA had a more favorable effect on total:HDL cholesterol ratio than any other FA studied (Mensink et al., 2003), indicating that ruminant milk containing higher proportions of MCFA may offer potential benefits with respect to human nutrition and health.

In light of the diverse biological activity of MCFA in ruminants, the current study examined the impact of ruminal administration of LA and CO on rumen fermentation characteristics and methane production, nutrient digestibility, urinary N losses, ammonia emitting potential of manure, and milk FA composition. The underlying experimental hypotheses being tested were that LA and CO would reduce methane production in the rumen, improve the efficiency of dietary N utilization, and enhance milk fat LA and MA content.

MATERIALS AND METHODS

Animals involved in this study were cared for according to the guidelines of the University of Idaho Animal Care and Use Committee. The committee reviewed and approved the experiment and all procedures carried out in the study.

Animals and Experimental Design

Six multiparous Holstein cows (682 ± 43.9 kg BW; 128 ± 25.2 DIM at the start of the trial) fitted with 10-cm ruminal cannulas (Bar Diamond, Parma, ID) were used. Cows were randomly assigned to experimental treatments in a replicated 3 × 3 Latin square design. Treatments were control (**SA**; 240 g of stearic acid/cow per d), **LA** (240 g of lauric acid/cow per d), and **CO** (530 g of coconut oil/cow per d). Lauric and stearic acids were from KIC Chemicals, Inc. (New Paltz, NY) and CO was food-grade 76 degree coconut oil (GloryBee Foods Inc., Eugene, OR) declared as containing 46 g of LA/100 g of FA. Other major FA in CO were (per 100 g of FA): MA, 20 g; 16:0, 11 g; monounsaturated FA, 7 g; 8:0, 6.1 g; 10:0, 5.5 g; 18:0, 3 g; and polyunsaturated FA (**PUFA**), 2 g. The application level of LA (and SA) was chosen based on previous studies (Hristov et al., 2004b), whereas the dose of CO was administered to provide approximately 240 g of LA. Stearic acid was used as a control treatment because it has minimal effects on ruminal fermentation (Hristov et al., 2004a). Treatments were applied as a pulse dose, once a day (immediately before morning feeding) directly into the rumen via the cannula by mixing with approximately 5 kg of whole ruminal contents. The basal diet was fed as a TMR (Table 1) and formulated (NRC, 2001) to meet or exceed the nutrient requirements (at 25 kg of DMI/d) of a Holstein cow yielding 35 kg of milk/d containing 3.70% milk fat and 3.20% true protein. Cows were offered the daily ration as equal meals at 07:00 and 18:00 h. Diets were fed ad libitum in amounts resulting in 5% refusals. Each experimental period was comprised of a 14-d treatment adaptation and 7 d for sampling. On the last day of periods 1 and 2, all cows were transfaunated with approximately 10 kg of whole ruminal contents/cow from donor cows fed the same basal diet (not supplemented with FA). Following a 7-d refaunation period (during which the cows were moved with the rest of the herd), the cows were assigned to new treatments. During the adaptation periods, the cows were housed in box stalls and then moved to tie stalls for the duration of the sampling period. Cows had continuous access to fresh water and did not receive recombinant bovine somatotropin during the trial.

Sampling and Measurements

Samples of forage, TMR, and refusals were collected daily and concentrate feeds were sampled weekly. Feed samples were composited and analyzed for DM (65°C in a forced-air oven, dried to a constant weight) and ash/OM (AOAC, 2000), N (Foley et al., 2006), NDF (Van Soest et al., 1991), and starch (starch assay kit,