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Effects of acetic acid or sodium acetate infused into the rumen or abomasum on feeding behavior and metabolic response of cows in the postpartum period

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ABSTRACT

Effects of continuous isomolar infusions of acetic acid (AcA) or sodium acetate (NAc) infused into the rumen (RU) or into the abomasum (AB) on feeding behavior, dry matter intake (DMI), and metabolic response of cows in the early postpartum period were evaluated. Six rumen-cannulated multiparous Holstein cows (11.8 ± 3.9 d in milk; mean ± SD) were utilized in a 6 × 6 Latin square design experiment balanced for carryover effects with a 2 × 3 factorial arrangement of treatments. Treatments were AcA and NAc, with sodium chloride (CON) as a control, infused at a rate of ~0.75 mol/h (0.5 L/h) into the RU or AB for the first 8 h following feeding, with a rest day between infusion days. Treatment sequences were assigned randomly to cows. Feeding behavior was recorded by a computerized data acquisition system and blood was sampled at 0, 4, and 8 h relative to the start of infusion. We hypothesized that AcA is more hypophagic than NAc, and that infusion into the AB is more hypophagic than infusion into the RU. Dry matter intakes (DMI) for the CON treatments were similar at 6.2 kg/8 h for RU and 6.1 kg/8 h for AB, and the AcA and NAc treatments interacted with site of infusion to affect DMI. The NAc-RU treatment did not reduce DMI (7.0 kg/8 h), whereas AcA-RU (2.6 kg/8 h), AcA-AB (3.7 kg/8 h), and NAc-AB (4.0 kg/8 h) decreased DMI compared with CON. Following infusions of AcA compared with NAc, there was a residual effect on DMI for the remainder of the day, but treatments did not affect DMI during the rest day. Treatments increased plasma acetate and β-hydroxybutyrate concentrations over time (interaction) and decreased plasma insulin concentration compared with CON. Plasma glucose concentration decreased over time after AcA-AB infusion compared with other treatments and CON. Plasma nonesterified fatty acid concentration increased over time for AcA compared with NAc and CON, suggesting an increase in lipolysis to compensate the decrease in DMI. In contrast to the other treatments, NAc-RU did not decrease DMI compared with control but we cannot determine the reason for this from the data available from the current study.
Key words: acetic acid, sodium acetate, infusion, metabolic response

INTRODUCTION

Acetic acid is the primary product of ruminal fermentation, typically comprising over 50% of the fermentation acids produced in the rumen on molar basis. It is used for fatty acid synthesis in adipose and mammary tissue and as an energy source by various tissues. Intraruminal infusions of acetic acid (**AcA**) or sodium acetate (**NAc**) have been used to test their effects on yields of milk and milk components and feed intake of lactating cows (Rook and Balch, 1961; Reynolds et al., 1979; Sheperd and Combs, 1998; Urrutia and Harvatine, 2017). Although some studies have infused AcA intraruminally (**RU**) without detrimental effects on DMI (Rook and Balch, 1961; Choi and Allen, 1999), others have reported a reduction in DMI (Montgomery et al., 1963; Wilson et al., 1967) or adverse physiological effects on the animals (e.g., cessation of rumination, decrease in ruminal pH, and symptoms of metabolic acidosis; Montgomery et al., 1963; Sheperd and Combs, 1998).

Our laboratory has used AcA alone or partially neutralized with sodium hydroxide intraruminally as control treatments to study the effects of propionate on feeding behavior of lactating cows. Infusions up to 28 mol of NAc (1.56 mol/h) or ~20 mol of AcA (0.75 mol/h) had no detrimental effect on the animals or reduction on feed intake (Choi and Allen, 1999; Oba and Allen, 2003a,b,c; Stocks and Allen, 2012, 2013). We considered that propionate is hypophagic compared with acetate because propionate is anaplerotic and

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stimulates hepatic oxidation of acetyl CoA in the tricarboxylic acid cycle, whereas acetate does not (Allen et al., 2009). Feeding behavior is affected by osmotic changes in the rumen so we rationalized that isosmotic infusions of acetate were appropriate controls for the propionate treatment. All previous experiments, to our knowledge, have infused AcA alone or partially neutralized with sodium hydroxide into the rumen. However, we recently observed adverse effects of abomasal (**AB**) infusion of 20.3 mol/d of AcA (4.2 Mcal/d) at a rate of 0.5 L/h (0.92 mol/h) to cows in the postpartum (**PP**) period (Gualdrón-Duarte, 2017) in which AcA decreased DMI 64% compared with control (no infusion). This was not expected because intraruminal infusions of AcA at this rate did not decrease DMI in previous experiments.

The objective of this experiment was to evaluate the effects of continuous isomolar infusions of AcA or NAc infused into the rumen or the abomasum on feeding behavior, DMI, and metabolic responses of cows in the PP period. We hypothesized that AcA would be more hypophagic than NAc, and that infusion into the AB would be more hypophagic than infusions into the RU.

MATERIALS AND METHODS

Animals and Care

All experimental procedures were approved by the Institutional Animal Care and Use Committee at Michigan State University, East Lansing. Cows were ruminally cannulated at least 45 d before parturition and housed in individual tiestalls for the 12-d duration of the experiment. All cows were fitted with a single jugular catheter 2 d before the beginning of the experiment, according to Bradford et al. (2006). Catheter patency was checked daily until the catheter was removed at the end of the experiment. Cows were withheld from feed at 0800 h and were not allowed access to feed until all blood samples were collected. Cows were fed once daily (0900 h) at 125% of expected ad libitum intake and milked twice daily (0530 and 1730 h). The amounts of feed offered and orts were weighed for each cow daily.

Experimental Design and Treatment Diets

Six ruminally cannulated multiparous, lactating Holstein cows (11.8 ± 3.9 DIM; mean ± SD) at the Michigan State University Dairy Teaching and Research Center were used in a 6 × 6 Latin square design experiment with a 2 × 3 factorial arrangement of treatments. Cows were assigned randomly to stalls and treatment sequence balanced for carryover effects. Infusion periods were 8 h long with continuous isomolar infusions (0.75 mol/h) of AcA (pH 2.3, >99.7%, Sigma Aldrich Chemical Co., St. Louis, MO), NAc (pH 5.9, AcA + NaOH), or NaCl (>99.5%, Sigma Aldrich Chemical Co.) as a control (**CON**), infused into the AB or RU at a rate of 0.5 L/h. Concentration of solutions and duration of infusions were 0.75 mol/h and 8 h, respectively, to limit potential adverse effects. Solutions were infused into the RU or AB using Baxter Flo-Gard 6201 infusion pumps (Baxter Medical Products, Deerfield, IL) through 2 vinyl tubes (0.95 cm outside diameter, 0.71 cm inside diameter). The first tube connected to a Nalgene bottle (3.8 cm diameter, 8.5 cm long), placed into the AB, and held by a semi-hard flexible rubber flange as described in Gualdrón-Duarte and Allen (2017), and the second tube was placed into the RU. A recovery period of 40 h was included between infusions.

All cows received a common experimental diet from parturition through the end of the experiment. The experimental diet was composed (DM basis) of corn silage (30%), ground corn (20%), soybean meal (16%), alfalfa silage (15%), alfalfa hay (14%), soy hulls (1.4%), and a vitamin and mineral mix (2.0%, containing 25.6% NaCl, 10.0% Ca, 2.0 Mg, 2.0% P, 30 mg/kg Co, 506 mg/kg Cu, 20 mg/kg I, 2,220 mg/kg Fe, 2,080 mg/kg Mn, 15 mg/kg Se, 2,030 mg/kg Zn, 300 kIU/kg vitamin A, 50 kIU/kg vitamin D, 1,500 kIU/kg vitamin E), sodium bicarbonate (1.1%), and limestone (1.1%), formulated to meet requirements for absorbed protein, minerals, and vitamins (NRC, 2001). The diet contained 52.4% DM and 28.7% NDF, with 24.3% NDF from forage, 22% starch, 17.4% CP, and 8.9% ash (DM basis).

Sample and Data Collection

Feed offered and refused was measured daily. Cows were blocked from feed from 0800 to 0900 h daily. Samples (0.5 kg) of all dietary ingredients and the TMR were collected daily throughout the experiment, and orts for each cow were taken at the end of each infusion period and stored in plastic bags at −20°C until processed. Feeding behavior data (feed disappearance and water intake) were recorded continuously for 22 h daily for each cow during infusion days via computer every 5 s, and size, length, and frequency of meals, intermeal interval, total eating time, and water intake were calculated (Dado and Allen, 1995).

Milk yield was recorded and milk samples were collected daily at each milking and stored with preservative (Bronopol tablet, D&F Control Systems, San Ramon, CA) at 4°C for component analysis (Universal