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Hypophagic effects of propionic acid are not attenuated during a 3-day infusion in the early postpartum period in Holstein cows[1]

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ABSTRACT

We previously showed that propionic acid was more hypophagic than acetic acid when infused intraruminally in cows in the postpartum period and that the degree of hypophagia from short-term propionic acid infusion (18 h) was related to the acetyl coenzyme A (CoA) concentration in the liver. The objective of this experiment was to evaluate adaptation over time with longer-term infusions over 3 d. Twelve multiparous cows (2–13 d postpartum) were blocked by calving date and assigned randomly to treatment sequence in a crossover design experiment. The experiment was 12 d long with covariate periods preceding each 3-d infusion period. Treatments were 1.0 *M* propionic acid or 1.0 *M* acetic acid, infused intraruminally at 0.5 mol of volatile fatty acids/h beginning 6 h before feeding and continuing for 78 h with 3 d between infusions. Propionic acid decreased dry matter intake (DMI) relative to acetic acid (15.9 vs. 17.0 kg/d). However, a period-by- treatment interaction was detected for DMI. During period 1, propionic acid decreased DMI relative to acetic acid (14.3 vs. 17.5 kg/d) because of a reduction in meal size (1.30 vs. 1.65 kg), with no effect on intermeal interval. Propionic acid decreased DMI over the first 4 h following feeding (5.86 vs. 8.23 kg) but did not affect DMI 4 to 24 h after feeding. The depression in DMI in period 1 was positively related to hepatic acetyl-CoA concentration during the covariate period. Propionic acid was increasingly more hypophagic than acetic acid as hepatic acetyl-CoA concentration was elevated. No treatment-by-day interaction for DMI was observed, suggesting little or no measurable adaptation to treatment over the 3-d infusion period. These results suggest that hypophagia from propionic acid is enhanced when hepatic acetyl-CoA concentrations are elevated, such as when cows are in a lipolytic state.

Key words: propionic acid, feeding behavior, lipolytic state

INTRODUCTION

In the weeks following parturition, cows are in negative energy balance as a result of increased energy demand at the onset of lactation and suppressed feed intake in the peripartum period (Ingvartsen and Andersen, 2000; Gulay et al., 2004). Whole-body glucose demand more than doubles following calving (Bell, 1995) and propionate accounts for up to 60% of hepatic glucose release during this time (Reynolds et al., 2003). To support milk production and improve energy balance after parturition, starch sources are included in diets to increase energy and provide glucose precursors (Allen et al., 2009). Ruminal starch fermentability varies from 50 to 94%, depending on processing method and grain type (Huntington, 1997), but limited research exists examining the effects of feeding a highly fermentable starch source after calving. Dann et al. (1999) reported that steam-flaked corn (a more ruminally fermentable starch source) tended to decrease DMI compared with cracked corn when fed to cows in the postpartum period. Greater ruminal fermentability of starch increases propionic acid production in the rumen (Oba and Allen, 2003a) and the flux of propionic acid to the liver increases rapidly following feeding (Benson et al., 2002).

Intraruminal propionic acid infusion has been shown to be hypophagic in ruminants and this effect is greater for cows early lactation compared with mid lactation (Oba and Allen, 2003b). Recent work in our laboratory has shown that hypophagic effects of propionic acid infusions are more pronounced when cows are in a lipolytic state (Stocks and Allen, 2012). Elevated plasma NEFA concentration during lipolysis increases the concentration of hepatic acetyl-CoA, which can be oxidized in the tricarboxylic acid cycle or exported as ketones. Intraruminal infusion of propionic acid reduces plasma BHBA concentration without reducing plasma NEFA concentration (Stocks and Allen, 2012), suggesting increased oxidation of liver acetyl-CoA, rather

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than a reduction in lipolysis leading to the reduction in plasma BHBA concentration. We proposed that propionic acid stimulates oxidation of hepatic acetyl-CoA in the tricarboxylic acid cycle, generating ATP and sending a satiety signal to brain feeding centers (Allen et al., 2009).

Despite consistent hypophagic effects of propionate during short-term infusions in our laboratory, the potential exists for adaptation over long-term infusions, which might affect feeding responses. Possible adaptations to propionic acid include altered concentrations of hormones or metabolites in plasma, or alterations in gene expression. Therefore, the objective of this experiment was to determine feeding response to longer-term (3 d) propionic acid infusion. We hypothesized that intraruminal infusion of propionic acid, compared with acetic acid, would decrease feed intake, but that the effects would be attenuated over time.

MATERIALS AND METHODS

Animals, Housing, and Diets

The Institutional Animal Care and Use Committee at Michigan State University (East Lansing) approved all experimental procedures for this experiment. Twelve multiparous, lactating Holstein cows were ruminally cannulated at least 45 d before calving and cows were housed in individual tie-stalls for the 12-d duration of the experiment. Cows were fed once daily (1200 h) at 115% of expected intake and received a common experimental diet from parturition through the end of the experiment. The experimental diet (Table 1) was composed of corn silage, alfalfa silage, alfalfa hay, ground corn, soybean meal, soy hulls, and a vitamin and mineral mix and formulated to meet requirements for absorbed protein, minerals, and vitamins (NRC, 2001).

Table 1. Ingredients and nutrient composition of the experimental diet

Item	Amount
Diet ingredient, % of dietary DM	
Corn silage	43.0
Alfalfa silage	29.4
Alfalfa hay	6.4
Ground corn	10.0
Soybean meal	7.2
Vitamin and mineral mix[1]	4.0
Nutrient composition, % of dietary DM	
DM, %	47.6
OM	93.0
Starch	19.1
NDF	38.6
ADF	28.8
CP	14.4
Ether extract	3.3

[1]Vitamin and mineral mix contained 24.8% ground corn grain, 21.5% dehydrated cane molasses, 11.2% limestone, 9.6% blood meal, 9.0% sodium bicarbonate, 6.6% dicalcium phosphate, 4.2% ReaShure choline (Balchem Corp., New Hampton, NY), 3.1% magnesium sulfate, 2.8% salt, 2.0% animal fat, 1.5% niacin, 1.3% trace mineral mix, 0.95% biotin, 0.70% Yeast Plus (Chr. Hansen, Milwaukee, WI), 0.54% vitamin ADE premix, 0.32% selenium yeast, and 0.09% Rumensin 90 (Elanco Animal Health, Greenfield, IN).

Experimental Design and Treatments

The experiment was a crossover design with a covariate day each period preceding the 3-d infusions to establish baseline measurements. Cows were between 2 and 13 d postpartum at the start of the experiment and were assigned to block by calving date, and then randomly assigned to treatment within a block. The experiment was 12 d long and conducted with 3 blocks of cows containing 4 cows each. Each covariate day (d 1 and 8), was 1 d before the start of infusions in each period. Following each covariate day was an 18-h rest period before the initiation of the infusion and there was a 3-d rest period between periods. Treatments were infused on d 3 to 5 (period 1) and d 10 to 12 (period 2) of the experiment. Jugular catheters were inserted according to the procedure of Bradford et al. (2006) 2 d before the start of the experiment and were maintained through the end of the experiment. Treatments were propionic or acetic acids (1 mol/L) infused continuously into the rumen at 0.5 mol of VFA/h for 78 h (39 mol/78-h infusion). Solutions were infused at 500 mL/h using peristaltic pumps (#78016–30; Cole-Parmer Instrument Co., Vernon Hills, IL) with Tygon tubing (1.6-mm i.d.) from individual containers that were manually replenished hourly to ensure an accurate hourly infusion rate. Infusions began 6 h before feeding on the first day of each infusion period to approach a steady state VFA concentration in the rumen before starting feeding behavior monitoring.

Cows were blocked from feed from 1000 to 1200 h daily to weigh and collect orts and fresh feed was offered at 1200 h. Samples of all diet ingredients (0.5 kg), the TMR (0.5 kg), and orts (12.5% of the remaining feed) were collected daily and composited into 1 sample per cow per block for analysis. Body weight and BCS were recorded on d 1 of the experiment. Body condition was scored by 3 trained investigators using a 5-point scale, where 1 = thin and 5 = fat, as described by Wildman et al. (1982). Cows were milked twice daily at 0500 and 1700 h in their stalls during covariate and infusion days and in the milking parlor on remaining days.

Covariate Sample and Data Collection

Feeding behavior was monitored for 24 h on each of the covariate days. Feeding behavior data (chewing,