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Effects of lipid and propionic acid infusions on feed intake of lactating dairy cows

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ABSTRACT

Propionic acid is more hypophagic for cows with elevated hepatic acetyl coenzyme A (CoA) concentration in the postpartum period. The objective of this experiment was to evaluate the interaction of hepatic acetyl CoA concentration, which is elevated by intravenous lipid infusion, and intraruminal propionic acid infusion on feed intake and feeding behavior responses of lactating cows. Eight multiparous, ruminally cannulated, Holstein dairy cows past peak lactation were used in a replicated 4 × 4 Latin square experiment with a 2 × 2 factorial arrangement of treatments. Treatments were propionic acid (PI) infused intraruminally at 0.5 mol/h for 18 h starting 6 h before feeding and behavior monitoring or sham control (CO), and intravenous jugular infusion of lipid (LI, Intralipid 20%; Baxter US, Deerfield, IL) or saline (SI, 0.9% NaCl; Baxter US) infused at 250 mL/h for 12 h before feeding and behavior monitoring, and then 500 mL/h for 12 h after feeding. Changes in plasma concentrations of metabolites and hormones and hepatic acetyl CoA from before infusion until the end of infusion were evaluated. We observed a tendency for an interaction between PI and LI for the change in plasma nonesterified fatty acid (NEFA) concentration from the preliminary day to the end of the infusion period. Infusion of propionic acid decreased dry matter intake (DMI) 15% compared with CO, but lipid infusion did not affect DMI over the 12 h following feeding. Infusion of propionic acid tended to decrease hepatic acetyl CoA concentration from the preliminary day to the end of the infusion compared with CO, consistent with PI decreasing DMI by stimulating oxidation of acetyl CoA. Contrary to our expectations, LI did not increase concentration of NEFA or β-hydroxybutyrate in plasma, concentration of acetyl CoA in the liver, or milk fat yield, suggesting that the infused lipid was stored or oxidized by extrahepatic tissues. As a result, we detected no interaction between PI and LI for DMI. Although the effect of PI on DMI was consistent with our previous results, this lipid infusion model using cows past peak lactation was not useful to simulate the lipolytic state of cows in the postpartum period in this experiment.
Key words: hepatic oxidation, hypophagia, lipid metabolism, propionate metabolism

INTRODUCTION

Dairy cows undergo substantial metabolic adaptations as they transition from late gestation to lactation. Energy demands are ~3-fold greater for lactation than for late gestation (as reviewed by Bell, 1995), and feed intake is often suppressed postpartum, resulting in negative energy balance (Doepel et al., 2002). Plasma glucose and insulin concentrations are low and tissue sensitivity to insulin is reduced during the immediate postpartum period (Bell and Bauman, 1997), elevating plasma NEFA and BHBA concentrations (Doepel et al., 2002). Elevated serum BHBA concentration greatly increases the risk of displaced abomasum, whereas elevated serum NEFA concentration increases risk of ketosis and likelihood of culling in the first 60 d postpartum (Seifi et al., 2011; Roberts et al., 2012). Therefore, careful management of the nutritional program through this time is necessary to meet the nutrient demands of cows in the first weeks following parturition to limit the extent and duration of lipolysis.

During the postpartum period, starch concentration in the diet is increased to provide glucose precursors to support milk production. As reviewed by Firkins et al. (2001), ruminal starch fermentability ranges from approximately 45 to 87%, depending on the type and processing of corn, and higher ruminal starch fermentability increases propionate production in the rumen as a fraction of total VFA (Davis, 1967). Propionate accounts for about 60% of the total hepatic glucose production for cows in early lactation (Reynolds, et al., 2003). However, previous research in our laboratory has demonstrated that propionic acid is hypophagic during the immediate postpartum period (Oba and Allen, 2003a; Stocks and Allen, 2012, 2013) and the extent of hypophagia is greater when cows are in a lipolytic state (Stocks and Allen, 2012, 2013). Our laboratory

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has also shown that increasing glucose demand with phlorizin reduces DMI, presumably by stimulating lipolysis (Bradford and Allen, 2007). These results are consistent with greater hypophagic effects of propionate for cows in a lipolytic state.

Despite this evidence that propionic acid is more hypophagic when cows are in a lipolytic state, experiments to test cause and effect between lipolytic state and propionic acid infusion on DMI are necessary. Experimental elevation of plasma NEFA concentration combined with infusion of propionic acid to test interactions among treatments for effects on feeding behavior will allow the interactions detected to be specifically attributed to increased oxidation of acetyl CoA. Lipid infusion is expected to increase NEFA supply to the liver and increase flux of carbon through acetyl CoA. The objective of this experiment was to evaluate the interaction of hepatic acetyl CoA concentration (which is elevated by intravenous lipid infusion) and intraruminal propionic acid infusion on feed intake and feeding behavior responses of lactating cows. We hypothesized that the hypophagic effects of propionic acid will be enhanced for cows receiving the lipid infusion.

MATERIALS AND METHODS

Animals, Housing, and Diets

The Institutional Animal Care and Use Committee at Michigan State University approved all experimental procedures for this experiment. Eight lactating, ruminally cannulated Holstein cows past peak lactation (81–252 DIM), with mean BW of 718 kg (±11 kg) and mean BCS of 2.65 (±0.54), were housed in individual tiestalls for the duration of the experiment. One cow was removed from the experiment because feed intake and milk yield were reduced by more than 75% after initiation of lipid infusion. Cows were fed at 115% of expected intake and received a common experimental diet. The experimental diet (Table 1) included corn silage, alfalfa silage, soybean meal, ground corn, and a mineral and vitamin mix, and it was formulated to meet requirements for absorbed protein, minerals, and vitamins (NRC, 2001).

Experimental Design and Treatments

The experimental design was a duplicated 4 × 4 Latin square with a 2 × 2 factorial arrangement of treatments. Cows were randomly assigned to block and treatment sequence, and squares were balanced for carryover effects. The experiment lasted 24 d and included an 8-d diet adaptation period followed by 4 infusion periods, each with 2 d for determination of digestibility, a 1-d preliminary period, and a 1-d infusion period (Table 2). On d 8, cows were fitted with bilateral jugular catheters according to Bradford et al. (2006) and catheters were maintained for the duration of the experiment. The treatments were propionic acid (1 mol/L; **PI**) infused continuously into the rumen at 500 mL/h for 18 h beginning 6 h before feeding or sham control (**CO**) and intravenous drip infusion of 20% Intralipid (**LI**; Baxter US, Deerfield, IL) or physiological saline (**SI**; 0.9% sodium chloride, pH 5.5; Baxter US) infused at 250 mL/h for 12 h before feeding and then 500 mL/h for the next 12 h. The lipid and saline control infusions were initiated at a lower rate to allow for a gradual increase in blood lipid concentration to avoid complications from inadequate adaptation. Propionic acid infusion began 6 h before feeding to allow propionate concentration in the rumen to approach steady state before measurement of feeding behavior. Propionic acid was infused using peristaltic pumps (no. 78016-30, Cole-Parmer Instrument, Vernon Hills, IL) with Tygon tubing (1.6 mm i.d.). The infusates were pumped from individual 1-L bottles that were manually refilled hourly to ensure accurate infusion rates.

Data and Sample Collection

Cows were blocked from feed from 1000 to 1200 h each day of the experiment to collect and weigh orts and to offer feed. Samples of all diet ingredients (0.5 kg) and orts (12.5% of remaining feed) were collected for the 3 d before each infusion day and on the infusion day and composited by infusion period. Body weight and BCS were recorded on d 1 of the experiment. Body condition was scored by 3 trained investigators on a 5-point scale, where 1 = thin and 5 = fat, as described

Table 1. Ingredients and nutrient composition of experimental diet (% of dietary DM except for DM)

Item	%
Ingredient	
Corn silage	50.7
Alfalfa silage	28.9
Ground corn	9.7
Soybean meal	6.2
Vitamin and mineral mix[1]	4.6
Nutrient composition	
DM	51.6
OM	92.4
Starch	21.1
NDF	36.3
ADF	23.9
CP	13.7

[1]Vitamin and mineral mix contained 60.4% ground corn grain, 18.8% limestone, 8.8% sodium bicarbonate, 4.0% urea, 3.1% magnesium sulfate, 2.9% salt, 0.63% trace mineral mix, 0.63% biotin, 0.63% vitamin ADE premix, and 0.20% selenium yeast.