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Temporal effects of ruminal propionic acid infusion on feeding behavior of Holstein cows in the postpartum period

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ABSTRACT

The objective of this study was to determine the temporal effects of intraruminal infusion of propionic acid at the initiation of meals on feeding behavior of cows in the postpartum period. Propionic acid derived from ruminal fermentation can reduce energy intake of dairy cows. The suppression of appetite by propionic acid is likely caused by a signal related to the hepatic oxidation of fuels. Greater propionate flux to the liver is expected to result in faster oxidation of acetyl coenzyme A, which can stimulate satiety and reduce feed intake. Therefore, the rate of propionate supply to the liver, within the timeframe of meals, might be an important limitation to feed intake. Our hypothesis was that faster rate of propionate infusion during meals would decrease meal size and feed intake by decreasing the time required to stimulate satiety within a meal. Six ruminally cannulated, multiparous Holstein cows in the postpartum period were used in a duplicated 3 × 3 Latin square design experiment balanced for carryover effects. Treatments included control (no infusion) or 1.25 mol of propionic acid infused over 5 min (FST) or 15 min (SLW) at each meal. Infusions were initiated at the conditioned meal at feeding (1200 h) and were triggered at each spontaneous meal for 22 h. Contrary to our hypothesis, SLW decreased meal size 29% (0.87 vs. 1.23 kg of dry matter) compared with FST, and FST decreased meal frequency 27% (8.5 vs. 11.2 per d) compared with SLW. Dry matter intake was similar between FST and SLW, but propionic acid decreased dry matter intake 46% compared with control. A potential explanation is that FST resulted in greater liver bypass of propionate compared with SLW, extending anaplerosis of the tricarboxylic acid cycle, hepatic oxidation of acetyl coenzyme A, and satiety over a longer time after meals.

Key words: appetite, feeding behavior, meal size, hepatic oxidation theory

INTRODUCTION

Maximizing intake in the postpartum period (**PP**) is critically important to the health, production, and profitability of dairy cows. However, the mechanisms controlling feed intake during the transition period are not completely understood. According to the hepatic oxidation theory, feeding behavior and feed intake are controlled by signals from the liver that are transmitted via hepatic vagal afferents to brain feeding centers (Allen et al., 2009). Increased hepatic oxidation of fuels likely decreases the firing rate of vagus, inhibiting feeding, whereas decreased hepatic oxidation increases its firing rate, stimulating feeding.

The hypophagic effects of propionate are well established, but the mechanism by which it affects feeding is unclear (Allen, 2000). Previous research showed that infusion of propionic acid (**PA**) decreased feed intake of cows (Choi and Allen, 1999; Stocks and Allen, 2012; Gualdrón-Duarte and Allen, 2017), and that DMI decreased linearly in response to increasing amounts of PA infused (Oba and Allen, 2003b). The rate of PA production in the rumen increases with diet starch content (Bauman et al., 1971; Sutton et al., 2003) and the starch content of diets fed to cows in the PP period varies widely. Furthermore, rumen digestibility of starch varies greatly, ranging from 224 to 942 g/kg, depending on the starch source (Moharrery et al., 2014). Variation in diet starch content and ruminal digestibility will result in very different rates of PA production, absorption, and flux to the liver. We hypothesized that a greater rate of propionate absorption within meals would stimulate hepatic oxidation and satiety sooner compared with a slower rate of absorption. Our objective was to determine the temporal effects of intraruminal infusion of PA on the feeding behavior of cows in the PP period. We expected that a faster rate of infusion would decrease meal size but increase the time between meals compared with a slower rate of infusion.

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MATERIALS AND METHODS

The Institutional Animal Care and Use Committee at Michigan State University approved all experimental procedures in this study.

Animals, Housing, and Diets

Multiparous Holstein cows (n = 8) from the Michigan State University Dairy Cattle Teaching and Research Center were ruminally cannulated at least 40 d prepartum and used in this experiment. Our goal was to evaluate the effects of treatment on cows during the PP that are in a lipolytic state. Feed intake and health were monitored following parturition. Six healthy cows with the lowest range in days PP were selected for the experiment and moved to the feeding behavior stalls for an adaptation period of 3 d before the first infusion day. Cows averaged 13.8 ± 2.9 DIM on first day of infusion, and all cows completed the experiment by 22 d PP.

The experimental diet (Table 1) was fed immediately following parturition and contained 16.0% CP, 32.9% NDF, 26.4% forage NDF, and 25.0% starch and consisted of corn silage, alfalfa silage, chopped alfalfa hay, ground corn, soybean meal, soy hulls, and a vitamin and mineral mix formulated to meet requirements according to NRC (2001). Cows were fed once a day (1200 h) at 110% of expected intake and feed offered was adjusted daily, if needed. Cows were not allowed access to feed between 1000 and 1200 h each day while orts and the amount offered were weighed for each cow.

Experimental Design and Treatments

The experimental design was a duplicated 3 × 3 Latin square. Cows were blocked by parturition date and randomly assigned to a treatment sequence within a square. Treatments included no infusion (control) and infusion of 1.25 mol of PA (99.5%, 0.5 *M*, Kemin Industries Inc., Des Moines, IA) over 5 (**FST**) or 15 (**SLW**) min into the rumen at the conditioned meal and at each spontaneous meal for 22 h. Infusion rates were selected in an attempt to maximize treatment differences while constraining the slow treatment to the expected length of a typical spontaneous meal. Past research in our laboratory with intraruminal infusions of PA used twice this rate at initiation of meals with no adverse effects (Choi and Allen, 1999). Solutions were infused into the rumen using peristaltic pumps (FPU401, Omegaflex Peristaltic Pump, Norwalk, CT) and Tygon tubing that passed through a hole in the cannula plug and was kept in place by stainless-steel hose clamp fixed in each side of the cannula plug. All cows were infused on the same day and a 24-h recovery period following infusion periods was allowed to reduce the potential for carryover effects.

Feeding Behavior

Feeding behavior was monitored using a computerized data acquisition system (Dado and Allen, 1993) programmed to trigger infusion pumps at the initiation of each new meal according to Choi and Allen (1999) and Bradford and Allen (2007b). Feed manger weights were monitored every 5 s, and when the running standard deviation reached threshold (average running SD greater than 0.9 kg), an eating flag was triggered. Infusions were initiated when at least 5 eating flags were triggered within 100 s to avoid false meals. To prevent mid-meal infusions, the eating flags were required to be triggered less than 13 times in the preceding 7.5 m, otherwise it would be counted as the part of the previous meal. Consecutive infusions began at least 15 min apart under both treatment protocols to prevent potential treatment bias.

Feed disappearance and water consumption were recorded for each cow every 5 s. Feeding behavior data were analyzed to quantify the number, size, length, and time between meals. Hunger ratio was calculated as the weight of meal divided by premeal interval and satiety ratio was calculated as the weight of meal divided by postmeal interval (Forbes, 2007). Triggering infusions based on real-time monitoring of feeding behavior resulted in reasonably good relationship between infusion events and meals, identified by post-hoc analysis. On average, there was a mean of 3 false-positives (infusions

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

Item	%
Ingredient	
Corn silage	45.0
Ground corn	10.9
Alfalfa haylage	21.6
Soybean meal	10.5
Alfalfa hay	6.2
Vitamin and mineral mix[1]	1.2
Sodium bicarbonate	0.64
Limestone	0.67
Nutrient composition	
DM	56.8
OM	91.3
Starch	25.0
NDF	32.9
Forage NDF	26.4
CP	16.0

[1]Vitamin and mineral mix contained 25.6% NaCl, 10.0% Ca, 2.0% Mg, 2.0% P, 30 mg/kg of Co, 506 mg/kg of Cu, 20 mg/kg of I, 2,220 mg/kg of Fe, 2,080 mg/kg of Mn, 15 mg/kg of Se, 2,030 mg/kg of Zn, 300 kIU/kg of vitamin A, 50 kIU/kg of vitamin D, and 1,500 kIU/kg of vitamin E.