J. Dairy Sci. 98:1–15
http://dx.doi.org/10.3168/jds.2014-8821

Metabolism of early lactation dairy cows as affected by dietary starch and monensin supplementation

M. M. McCarthy,* T. Yasui,* C. M. Ryan,* S. H. Pelton,* G. D. Mechor,† and T. R. Overton*[1]
*Department of Animal Science, Cornell University, Ithaca, NY 14853
†Elanco Animal Health, Greenfield, IN 46140

ABSTRACT

The objective of this study was to evaluate the effect of dietary starch content and monensin (MON) on metabolism of dairy cows during early lactation. Before parturition, primiparous (n = 21) and multiparous (n = 49) Holstein cows were fed a common controlled-energy close-up diet with a daily topdress of either 0 or 400 mg/d monensin. From d 1 to 21 postpartum, cows were fed a high-starch (HS; 26.2% starch, 34.3% neutral detergent fiber, 22.7% acid detergent fiber, 15.5% crude protein) or low-starch (LS; 21.5% starch, 36.9% neutral detergent fiber, 25.2% acid detergent fiber, 15.4% crude protein) total mixed ration with a daily topdress of either 0 mg/d monensin (CON) or 450 mg/d monensin (MON), continuing with prepartum topdress assignment. From d 22 through 63 postpartum, all cows were fed HS and continued with the assigned topdress treatment until d 63. Cows fed HS had higher plasma glucose and insulin and lower nonesterified fatty acids (NEFA) than cows fed LS during d 1 to 21 postpartum. Cows fed LS had elevated early-lactation β-hydroxybutyrate (BHBA) compared with cows fed HS. Cows fed HS had greater insulin resistance and increased plasma haptoglobin in the early lactation period. There was no effect of MON on postpartum plasma NEFA. Cows fed MON had higher plasma glucose compared with CON cows, which was driven by a MON × parity interaction in which primiparous cows fed MON had greater plasma glucose concentrations than cows fed CON. Cows fed MON had lower plasma BHBA compared with CON, which was contributed to by a MON × parity interaction in which primiparous cows fed MON had lower BHBA concentrations than CON. Starch treatment had no effect on overall liver triglyceride content. Primiparous cows fed MON had increased liver triglyceride content compared with CON primiparous cows, and multiparous cows fed MON had decreased liver triglyceride content compared with CON cows. Multiparous cows fed LS with MON had higher liver glycogen content than multiparous cows fed the LS without MON, with no effect of MON treatment for multiparous cows fed HS. There was no effect of starch or MON treatment on liver capacity to oxidize propionate to CO_2, and effects of starch on gluconeogenesis were not significant. Cows fed MON tended to have greater capacity to convert propionate to glucose than CON. Supplementation with MON increased the ratio of glucose to CO_2, which indicated that cows fed MON had a greater propensity to convert propionate to glucose. Overall, cows fed more propiogenic diets in early lactation (high starch or monensin) exhibited improved energy metabolism during early lactation.
Key words: early lactation, metabolism, starch, monensin

INTRODUCTION

Many postpartum metabolic disorders are the result of insufficient energy intake in the period immediately surrounding parturition. After calving, DMI is insufficient to support the high milk production of early lactation and results in a state of negative energy balance (**EB**), leading to greater mobilization of adipose tissue and release of NEFA into circulation to be metabolized by the liver (Drackley, 1999). Higher energy intake postpartum results in lower circulating NEFA (Andersen et al., 2004; Rabelo et al., 2005) and has been associated with improved health (Ospina et al., 2010), performance (Andersen et al., 2003; Rabelo et al., 2003), and less severe postpartum negative EB (Ingvartsen and Andersen, 2000).

The fermentation of starch in the rumen favors production of propionate, which is the main precursor for hepatic glucose production, and supplementation with monensin (an ionophore) has been shown to increase ruminal propionate production (Armentano and Young, 1983). It has been observed that cows fed higher-energy diets postpartum (Andersen et al., 2002, 2004; Rabelo et al., 2005) and monensin during the peripartal period

Received September 4, 2014.
Accepted February 5, 2015.
[1]Corresponding author: tro2@cornell.edu

(Arieli et al., 2008; Duffield et al., 2008a) have improvements in postpartum energy metabolism.

The hepatic oxidation theory proposed by Allen et al. (2009) would suggest that feeding diets that promote greater ruminal propionate production (e.g., high in fermentable starch, monensin supplementation) during early lactation would be hypophagic and further exacerbate the state of negative EB due to the increased oxidation of propionate in the liver. However, it has been observed that cows fed more propiogenic diets have increased DMI in early lactation (Andersen et al., 2003; Rabelo et al., 2003; McCarthy et al., 2015). The hypophagic effect of propionate is likely to be reduced in the immediate postpartum period because of the large increase in hepatic energy demands at the onset of lactation (Reynolds et al., 2003). The increase in early-lactation NEFA mobilization (Vernon, 2005) and subsequent hepatic uptake of NEFA and mitochondrial β-oxidation of fatty acyl CoA to acetyl CoA provide substantial amounts of oxidative substrate, in addition to propionate, to the tricarboxylic acid cycle (Drackley et al., 2001).

When there is an increase in propionate supply to the liver, early-lactation cows appear to have an increased propensity to convert the propionate to glucose rather than oxidize it (Drackley et al., 2001). The rate of gluconeogenesis from [1-^{14}C]propionate in liver slices from early-lactation cows are increased compared with the rate in liver slices from the same cows once they have reached mid-lactation (Aiello et al., 1989). Drackley et al. (2001) found a positive correlation between carbohydrate intake in the immediate postpartum period with the efficiency of [1-^{14}C]propionate conversion to glucose in liver biopsy slices, which would suggest that the liver has the capacity to direct additional propionate toward glucose during early lactation.

Monensin has been shown to decrease the incidence of periparturient health disorders associated with negative EB and improve energy metabolism (Duffield et al., 2008b,c). However, it is of interest to determine whether effects of monensin in fresh cows are independent of dietary starch content, as both will likely increase supply of propionate, leading to increased hepatic oxidative supply. The objectives of this study were to evaluate the effect of dietary starch content during the immediate postpartum period and monensin inclusion during the periparturient and early-lactation period on metabolic indices related to energy metabolism and in vitro hepatic gluconeogenesis. We hypothesized that increasing the starch content during the immediate postpartum period and feeding monensin throughout the periparturient period and into early lactation would increase hepatic gluconeogenesis as well as improve measures of energy metabolism.

MATERIALS AND METHODS

Animals and Dietary Treatments

All animal procedures were approved by the Cornell University Institutional Animal Care and Use Committee, and the experiment was conducted from March to October 2012. The experimental design and treatments were described more completely in the companion paper (McCarthy et al., 2015). Briefly, the study was a completely randomized design with randomization restricted to balance for expected calving date of primiparous and multiparous cows and previous lactation 305-d mature-equivalent milk production for multiparous cows. A 2 × 2 factorial arrangement of postpartum treatments was used, with early-lactation period feeding strategy [high starch (**HS**) vs. low starch (**LS**) diet during the first 21 d postpartum] and monensin supplementation [0 mg of monensin/d (**CON**) or 450 mg of monensin/d (**MON**); monensin; Elanco Animal Health, Greenfield, IN] as the variables of interest. In addition, cows that received MON during the postpartum period were fed MON (400 mg/d) initiated on 1 d between d 21 and 28 before expected parturition (average treatment of 25 d; minimum of 14 d on treatment before actual parturition was required for inclusion in the data set). The final data set included 70 cows (primiparous n = 21, multiparous n = 49). Lactating cows were dried off at least 45 d (average dry period length of 53 d) before expected parturition and moved to the experimental tie-stall barn approximately 28 d before expected parturition, where they began consuming the experimental close up dry cow diet.

Diet ingredients are presented in Table 1 and nutrient composition is shown in Table 2. Procedures and methods for feed sampling and analysis are detailed in McCarthy et al. (2015). The topdress pellets were formulated to contain either 0 (CON) or 461 g/t monensin (MON) and were fed as a daily topdress at rates of 0.85 kg/d prepartum and 0.95 kg/d postpartum. The MON topdress was targeted to provide 400 mg/d prepartum and 450 mg/d postpartum. Cows continued to receive assigned topdress treatments through d 63 postpartum.

Plasma and Tissue Sampling and Analyses

Blood samples were collected via venipuncture of the coccygeal vessels using heparinized Vacutainer (Becton Dickinson, Franklin Lakes, NJ) tubes 1 h before feeding. Blood samples were collected 1×/wk prepartum beginning the week before commencement of prepartum topdress treatments, 3×/wk from calving through 21 d postpartum, and 1×/wk from d 22 to 63. Blood samples were placed on ice immediately following col-