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Dry period plane of energy: Effects on glucose tolerance in transition dairy cows

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ABSTRACT

Overfeeding energy in the dry period can affect glucose metabolism and the energy balance of transition dairy cows with potential detrimental effects on the ability to successfully adapt to early lactation. The objectives of this study were to investigate the effect of different dry cow feeding strategies on glucose tolerance and on resting concentrations of blood glucose, glucagon, insulin, nonesterified fatty acids (NEFA), and β-hydroxybutyrate (BHB) in the peripartum period. Cows entering second or greater lactation were enrolled at dry-off (57 d before expected parturition) into 1 of 3 treatment groups following a randomized block design: cows that received a total mixed ration (TMR) formulated to meet but not exceed energy requirements during the dry period (n = 28, controlled energy); cows that received a TMR supplying approximately 150% of energy requirements during the dry period (n = 28, high energy); and cows that were fed the same diet as the controlled energy group for the first 28 d, after which the TMR was formulated to supply approximately 125% of energy requirements until calving (n = 28, intermediate energy). Intravenous glucose tolerance tests (IVGTT) with rapid administration of 0.25 g of glucose/kg of body weight were performed 28 and 10 d before expected parturition, as well as at 4 and 21 d after calving. Area under the curve for insulin and glucose, maximal concentration and time to half-maximal concentration of insulin and glucose, and clearance rates were calculated. Insulin resistance (IR) indices were calculated from baseline samples obtained during IVGTT and Spearman rank correlations determined between IVGTT parameters and IR indices. Treatment did not affect IVGTT parameters at any of the 4 time points. Correlation between IR indices and IVGTT parameters was generally poor. Overfeeding cows energy in excess of predicted requirements by approximately 50% during the entire dry period resulted in decreased postpartum basal plasma glucose and insulin, as well as increased glucagon, BHB, and NEFA concentrations after calving compared with cows fed a controlled energy diet during the dry period. In conclusion, overfeeding energy during the entire dry period or close-up period alone did not affect glucose tolerance as assessed by IVGTT but energy uptake during the dry period was associated with changes in peripartal resting concentrations of glucose, as well as postpartum insulin, glucagon, NEFA, and BHB concentrations.
Key words: dairy cow, transition period, energy, glucose, insulin

INTRODUCTION

The transition period represents a metabolic challenge to dairy cows because of the rapid increase of required nutrients, particularly for milk production. Excessive negative energy balance and hyperketonemia (defined as a blood concentration of BHB ≥1.2 mmol/L) in the postpartum period are associated with detrimental effects on health and productivity of dairy cows (Duffield et al., 2009; McArt et al., 2013b). Feeding of high energy diets during the dry period increases the degree of lipid mobilization and ketogenesis postpartum (Dann et al., 2006; Janovick et al., 2011; Mann et al., 2015). Several studies have attempted to elucidate the cause of this postpartum effect on ketogenesis in dairy cows overfed energy prepartum.

Schoenberg and colleagues (Schoenberg and Overton, 2011; Schoenberg et al., 2012) investigated how plane of nutrition affected the response of dry cows to a glucose

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challenge in 2 experiments. In these experiments, cows were fed either approximately 90 or 160%, or 120 and 170% of predicted energy requirements during the dry period. Diet had no effect on the insulin response in both studies, but cows fed 90% of energy requirements tended to have higher glucose area under the curve, decreased glucose clearance, and greater nonesterified fatty acids (**NEFA**) response compared with overfed cows. However, no measurements were taken postpartum, including glucose tolerance tests. Holtenius et al. (2003) found a numerically higher insulin peak and higher glucose clearance prepartum, whereas glucose clearance was reduced postpartum following a glucose challenge in cows overfed energy during the dry period compared with cows fed a lower energy diet. They hypothesized that the observed postpartum changes are evidence of a greater degree of insulin resistance (**IR**) in cows overfed energy during the dry period, leading to more lipolysis and higher blood NEFA concentration. However, sample size was relatively small and different genetic selection lines were used.

Several studies have aimed to describe how overfeeding in the dry period affects resting concentrations of insulin and glucose in the peripartum period. Overfeeding energy during the far-off and close-up dry period (Dann et al., 2006) and during the entire dry period (Holtenius et al., 2003; Douglas et al., 2006; Janovick et al., 2011) was associated with increased insulin concentrations prepartum compared with controlled or restricted fed cows. Overfeeding during the close-up period (Dann et al., 2006) or the whole dry period (Douglas et al., 2006) resulted in higher prepartum glucose concentrations compared with cows fed restricted energy. Cows fed a controlled energy diet during the whole dry period tended to have greater insulin concentrations postpartum compared with overfed cows (Janovick et al., 2011). However, other studies showed no effect of overfeeding during the dry period on peripartal plasma glucose, glucagon, and insulin (Selim et al., 2015) or postpartal glucose and insulin concentrations (Khan et al., 2014; Schulz et al., 2014). In light of the differences found in these studies, evidence is lacking to assess whether overfeeding during the entire dry period or during close-up alone leads to peripartal changes in glucose disposal, glucose availability, or both. Because excess energy intake affects insulin sensitivity in humans (Capurso and Capurso, 2012; Johnson and Olefsky, 2013), changes in resting concentrations of insulin as well as insulin response to a glucose challenge and glucose clearance are also of interest in this context in the bovine species.

Our objective was therefore to investigate the effect of different dry period planes of energy on glucose disposal by repeated intravenous glucose tolerance test in periparturient dairy cows and to evaluate the effect on resting concentrations of blood glucose, insulin, and glucagon as well as NEFA and BHB.

MATERIALS AND METHODS

Animals, Feeding, and Management

All procedures were approved by the Cornell University Institutional Animal Care and Use Committee. A detailed description of animals, feeding, and management was reported previously (Mann et al., 2015). In brief, Holstein cows (n = 84) entering second or greater lactation from the herd at the Cornell Teaching and Research Center were enrolled between September 2012 and April 2013. All animals were housed in individual sawdust-bedded tiestalls equipped with individual feed bins. Cows were allocated to 1 of 3 dry-period dietary treatment groups using a randomized block design to control for time-dependent variation with 3 treatments in 28 blocks on the day of dry off (approximately 57 d before expected parturition). Blocking was based on expected calving date. Random sequence of allocation within the block was determined with a random number generator (Research Randomizer v.4.0; Urbaniak and Plous, 2012). Groups did not differ in BCS (on a scale of 1.0 to 5.0 according to Edmonson et al., 1989) of animals at enrollment or in the distribution of parity (Mann et al., 2015). Animals were enrolled in 1 of 3 feeding groups: a TMR formulated to meet 100% of energy requirements at predicted ad libitum intake (controlled energy, **C**); a TMR formulated to supply 150% of energy requirements (high energy, **H**); and an intermediate group that received the same TMR as group C for the first 28 d after dry off and a TMR formulated to supply 125% of energy requirements from d 28 before expected parturition until calving (intermediate energy, **I**, representing a 50:50 blend of both C and H diets). On a DM basis, conventional corn silage accounted for 28.5, 42.2, and 55.9% in diets C, I, and H, respectively, and wheat straw was included at 35.6, 24.0, and 12.4% of DM in groups C, I, and H, respectively. All cows received the same fresh cow TMR from the onset of lactation until the end of the study period (42 DIM). Milk yield was measured at every milking (0900 and 2100 h). Rations were formulated using the Cornell Net Carbohydrate and Protein System software (CNCPS version 6.1; Cornell University, Ithaca, NY). Samples of all TMR were taken weekly and analyzed based on a monthly composite at a commercial laboratory with wet chemistry methods (Dairy One Cooperative Inc., Ithaca, NY). All diets were offered ad libitum fed once daily at 0900 h, and amounts fed were adjusted to allow for a minimum of 5% refusals.