Effects of Monensin on Metabolic Profile and Feeding Behavior of Transition Dairy Cows

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Summary
Thirty-two Holstein transition cows were used to determine the effects of monensin (Rumensin, Elanco Animal Health, Greenfield, IN; 400 mg/cow daily) on metabolism and feeding behavior. Cows were assigned randomly, based on calving date, to control or monensin treatments (n = 16 per treatment) 21 days before their expected calving date, and cows remained on treatments through 21 days in milk. Feeding behavior and water intake data were collected daily. Blood samples were collected at 8 different time points during the experimental period. Monensin decreased mean and peak plasma ketone concentrations, and also decreased time between meals before and after calving. No effects of monensin supplementation were observed on milk production or other metabolic traits. Furthermore, we observed no treatment effects on disease incidence, although sample size was small for detecting such effects.

Key words: monensin, transition cow, feeding behavior

Introduction
The weeks surrounding calving are a critical time in the life cycle of a dairy cow. During this period, cows make many metabolic adjustments to support the transition from pregnancy to lactation. Feed intake can be directly linked to a successful transition. Recent research indicates a beneficial effect of monensin on postpartum feed intake, but the mechanism responsible for improved intake is not clear. Research from feedlot cattle suggests dietary monensin could modulate intake patterns, thus reducing dramatic changes in rumen pH while cattle are adapting to a higher-energy diet.

Furthermore, in recent years, monensin has been used to help mitigate the effects of a transition-related negative energy balance, which traditionally has been attributed to its ability to promote the production of glucose precursors. However, investigators across the country have uncovered evidence suggesting that the beneficial effects of monensin actually may be independent of changes in glucose production.

The primary objectives of this study were to determine the effects of monensin on transition cow feeding behavior and metabolic parameters. The secondary objectives were to assess the effects of monensin on productivity and disease incidence of transition cows.

Experimental Procedures
Thirty-two Holstein transition cows were assigned to a control or treatment group 21 days before their expected calving date (16 cows per treatment). Cows remained on their respective treatments through 21 days postpartum. Treatment cows received monensin (Rumensin, Elanco Animal Health) as a top-dress at a rate of 400 mg/cow per day. Monensin was premixed into a ground corn carrier and 2 lb of the premix was top-dressed once daily to each treatment cow. The controls received no monensin in 2 lb of the same ground corn carrier for the duration

of the study. Diets were formulated to meet or exceed National Research Council requirements (Table 1). Cows were dried off approximately 45 days before expected calving date. Monensin was excluded from the far-off dry cow ration to help ensure that no cows entering the study were influenced by prior monensin exposure.

Management of Cows and Data Collection. Cows were allowed ad libitum access to the designated treatment rations by an electronic gating system, with one cow assigned per gate. After parturition, cows were moved into a tie-stall facility where they were housed for the remainder of the study. Dry cows were fed twice daily (8:00 a.m. and 3:30 p.m.) to accommodate the capacity of the feeding system used prepartum. Lactating cows were fed once daily (3:00 p.m.) to minimize the time during which feeding behavior could not be recorded.

Cows were milked 3 times daily in a milking parlor, and milk yield was recorded at each milking. Milk samples were collected during each milking beginning at 4 days in milk and continuing through 21 days in milk. Body condition score (**BCS**; 1=thin and 5=fat) and body weight was measured 2 hours before feeding on days −21 and −7 relative to expected calving, and on days 1, 7, and 21 postpartum. Blood was collected 2 hours before feeding on these days, as well as on days -4, 4, and 14 relative to calving.

Postpartum cows (and prepartum cows with abnormalities) underwent a daily health inspection, including monitoring for urine ketones and rectal temperature. Health records were kept throughout the study to register disease incidence. If cows displayed a disorder, they were treated according to on-site standard operating procedures.

Results and Discussion

Feed Intake and Milk Production. Daily feed intake is shown in Figure 1A. As expected, average daily intake declined before calving and increased after calving in both treatments. Dry matter intake was not affected by treatment during the pre- or postpartum periods. This result was surprising because other transition cow research has shown monensin to have an effect on feed intake.

Although intakes were similar, monensin supplementation decreased ($P < 0.03$) time between meals before calving and tended ($P < 0.08$) to decrease time between meals postpartum (Table 2 and Figure 1B). These findings align with reports showing that inclusion of monensin in feedlot diets resulted in more consistent patterns of feed intake throughout the day. Even though the intermeal interval was shorter with monensin supplementation, the number of meals consumed per day and average meal duration did not differ between treatments. Meal sizes were similar overall (Table 2), but a treatment by day interaction was observed for postpartum meal size. In other words, monensin increased meal sizes on days 8, 15, 20, and 21 (Figure 1C), but not on other postpartum days. The small increase in meal frequency, coupled with similar to larger meal sizes, resulted in small, non-significant increases in dry matter intake for monensin-supplemented cows during the postpartum period. As expected, intake was noticeably different pre- and postpartum; however, the dramatic decrease in meal duration (Table 2) for postpartum cows compared with prepartum cows likely reflects differences in feeding behavior of cows in tie-stall vs. pen housing rather than a true stage of production effect. Previous studies have shown that cows in pen settings eat fewer, larger meals each day than cows housed in tie-stalls.

Daily water consumption did not differ between treatments throughout the experimental period (Table 2). Postpartum water intake started at approximately 20 gal/day, and, as expected, increased ($P < 0.001$) to 30 gal/day by day 21.

Cows receiving monensin tended ($P < 0.09$) to have smaller body weights on day 1 postpartum, but no other differences were observed between treatments for BCS or body weight (data not shown). On average, cows lost 0.6 BCS units (3.3 to 2.7) during the experiment. Milk production (85.9 vs. 86.6 ± 3.7 lb/day for control and monensin, respectively; $P = 0.92$) and concentrations of fat, protein, lactose, and solids-non-fat did not differ between dietary treatments, but milk urea nitrogen (**MUN**) was greater ($P < 0.02$) for monensin-supplemented cows (11.8 vs. 10.4 ± 0.42 mg/dL). We have no clear explanation for the observed effect on MUN; it could be related to impaired liver function in the control or a result of monensin's ruminal protein sparing effect, allowing more escape protein to reach the small intestine. A simpler explanation, however, is to consider that monensin-supplemented cows consumed, on average, an additional 0.51 lb/day of protein, with no increase in milk protein yield. If metabolizable protein supply did not limit milk protein yield, then the increase in MUN for the monensin treatment was an expected response to increased protein intake.

Metabolic and Endocrine Changes. Plasma non-esterified fatty acids (**NEFA**), ketones, glucose, and insulin concentrations are displayed in Figure 2. As expected, plasma NEFA concentrations increased dramatically before expected calving, to a peak of 878 ± 80 μM on day 1 postpartum (Figure 2A; $P < 0.001$). Monensin supplementation did not significantly alter NEFA concentrations throughout the study. This was somewhat unexpected, because previous research demonstrated that monensin could decrease NEFA concentration.

Monensin treatment decreased ($P < 0.05$) plasma ketone β-hydroxybutyrate concentration during the entire study (734 vs. 616 ± 40.9 μM). The effect of treatment day ($P < 0.001$) and a treatment by day interaction ($P < 0.01$; Figure 2B) were also significant. Most notably, monensin decreased ($P < 0.01$) plasma β-hydroxybutyrate on day 4 postpartum (777 vs. 1077 ± 71 μM). The effect on β-hydroxybutyrate is not surprising given that many other reports have demonstrated similar decreases in β-hydroxybutyrate. Smaller β-hydroxybutyrate concentrations in response to monensin are likely a result of more complete fatty acid oxidation in the liver.

Plasma glucose concentrations decreased after parturition in both groups ($P < 0.001$), but monensin did not affect pre- or postpartum plasma glucose concentrations (Figure 2C). Previous work indicates that monensin can increase plasma glucose concentration of transition cows, but increases were not consistently reported. Furthermore, because monensin does not always affect ruminal propionate production in transition cows, we would not expect substrate-driven changes in liver glucose production, although monensin could also alter gluconeogenic enzyme capacity.

Overall, monensin treatment did not affect plasma insulin concentration (Figure 2D); however, a tendency for higher plasma insulin concentration in monensin-fed cows was detected on day 7 postpartum ($P < 0.08$). Interestingly, 5 other studies failed to observe an effect of monensin on insulin concentration in transition cows, making increased insulin concentration unlikely to be a primary mechanism by which monensin alters transition cow metabolism.

Management and Health. Incidence of health disorders is shown in Table 3. No differences were detected between treatments. Because only 32 cows were used for this study, detecting dif-

ferences in disease incidence is unlikely. A more powerful assessment of the effects of monensin on cow health is the meta-analysis of 16 different studies conducted by scientists at the University of Guelph. Overall, monensin significantly decreased the relative risk of ketosis, displaced abomasum, and mastitis. The β-hydroxybutyrate response observed in our study is consistent with the numbers reported in that meta-analysis. Therefore, monensin likely reduces the risk of diseases such as ketosis and displaced abomasa, although our study lacked statistical power to detect these differences.

In this first report of monensin's effects on feeding behavior, monensin increased meal frequency. Consistent with previous results, monensin significantly decreased plasma β-hydroxybutyrate concentrations in postpartum cows, but did not alter concentrations of plasma NEFA, glucose, or insulin during early lactation. Despite the observed beneficial effects on metabolism, no significant effects on milk production or disease incidence were detected.

Table 1. Ingredient and nutrient composition of diets

Item	Prepartum	Postpartum
Ingredient, % of dry matter		
Corn silage	30.3	34.0
WCGF[1]	19.6	21.5
Prairie hay	39.7	...
Alfalfa hay	...	16.6
Cottonseed	...	6.7
Corn grain[2]	6.5	12.4
Soybean meal 48	4.1	...
Expeller soybean meal	...	7.1
Micronutrient premix[3,4]	0.3	2.8
Nutrient, % of dry matter		
Dry matter, % as-fed	57.2	54.2
Crude protein	13.1	17.3
Acid detergent fiber	28.4	19.7
Neutral detergent fiber	49.9	36.0
Nonfiber carbohydrates	35.5	38.0
Ether extract	3.4	5.0
Ash	6.9	8.8
NE_L, Mcal/lb[5]	0.72	0.76

[1] Wet corn gluten feed (Sweet Bran, Cargill, Inc., Blair, NE).
[2] A portion of the daily corn grain (2 lb/cow) served as the top-dress carrier for 400 mg monensin (Rumensin, Elanco Animal Health, Greenfield, IN) for supplemented cows. The same amount of corn alone was top-dressed for control cows.
[3] Prepartum premix consisted of 42.6% vitamin E premix, 11.9% Se premix, 11.6% trace mineral salt, 10.8% limestone, 9.71% vitamin A premix, 6.47% 4-plex, 4.31% vitamin D premix, 2.17% magnesium oxide, and 0.53% ethylenediamine dihydroiodide.
[4] Postpartum premix consisted of 48.4% limestone, 27.3% sodium bicarbonate, 12.6% trace mineral salt, 6.04% magnesium oxide, 2.33% 4-plex, 1.51% Se premix, 1.16% vitamin E premix, 0.46% vitamin A premix, 0.21% vitamin D premix, and 0.03% ethylenediamine dihydroiodide.
[5] Estimated according to NRC (2001). Nutrient Requirements of Dairy Cattle, 7th rev. ed., National Research Council. Natl. Acad. Sci., Washington, DC.

Table 2. Feed and water intake and feeding behavior during the transition period

Item	Control	Monensin	SEM	*P*-value
Prepartum water intake, gal/day	5.4	5.0	0.4	0.48
Prepartum dry matter (DM) intake, lb/day	30.6	31.1	1.3	0.83
Intermeal interval, min.	143	126	5.0	0.03
Meal frequency, meals/day	7.57	8.05	0.36	0.35
Meal size, lb DM	4.08	4.08	0.26	0.99
Meal length, min	43.4	42.9	2.3	0.88
Postpartum water intake, gal/day	26.8	26.8	2.7	0.99
Postpartum DM intake, lb/day	40.6	43.7	0.7	0.14
Intermeal interval, min.	88.8	81.4	2.9	0.08
Meal frequency, meals/day	13.7	14.8	0.5	0.12
Meal size[1], lb DM	3.04	3.24	0.13	0.29
Meal length, min.	14.1	14.5	0.6	0.65

[1] Treatment by day interaction ($P < 0.02$).

Table 3. Incidence of health disorders during the experimental period

Disorder[1]	Control	Monensin
Retaind placenta	0	1
Body temperature (fever) > 103°F	5	7
Ketosis	5	3
Hypocalcemia	2	0
Metritis	1	1
Mastitis	7	5
Displaced abomasum	2	1
Other digestive disorder	4	3
One or more disorders	12	11
Dystocia[2]	3	5

[1] No differences were detected between treatment groups using Fisher's exact test.
[2] Dystocia was defined as a calving difficulty score > 1.

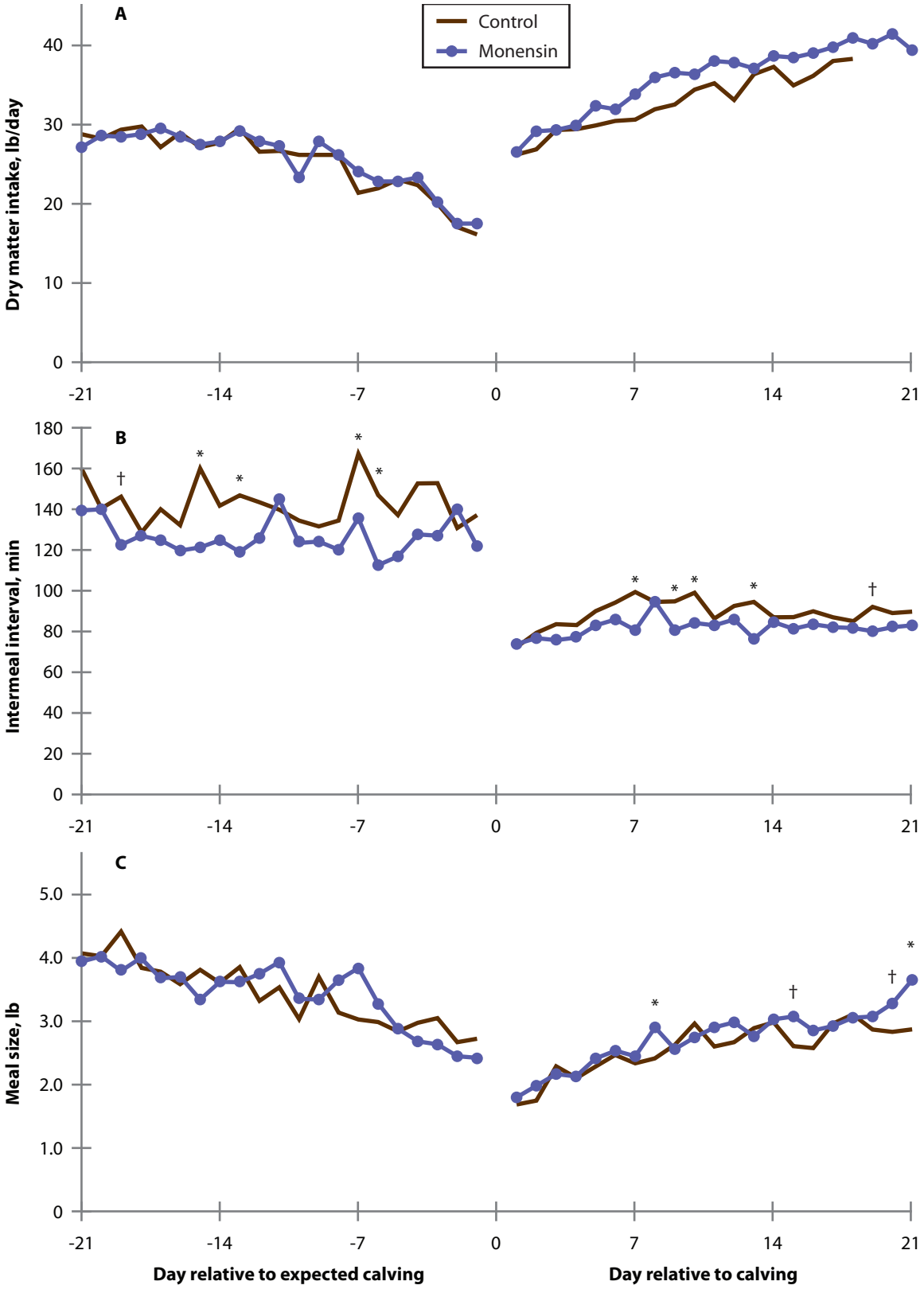

Figure 1. Dry matter intake (A), intermeal interval (B), and meal size (C) during the experimental period.

A. There was an effect ($P < 0.001$) of pre- and postpartum day (prepartum SEM = 1.94, postpartum SEM = 1.92). B. Monensin shortened ($P < 0.03$) prepartum intermeal interval and tended ($P = 0.08$) to shorten postpartum intermeal interval. An effect ($P < 0.001$) of postpartum day was detected (prepartum SEM = 10.6, postpartum SEM = 4.77; †$P < 0.10$; *$P < 0.05$). C. A postpartum treatment by day interaction was detected ($P < 0.02$; prepartum SEM = 0.4, postpartum SEM = 0.2).

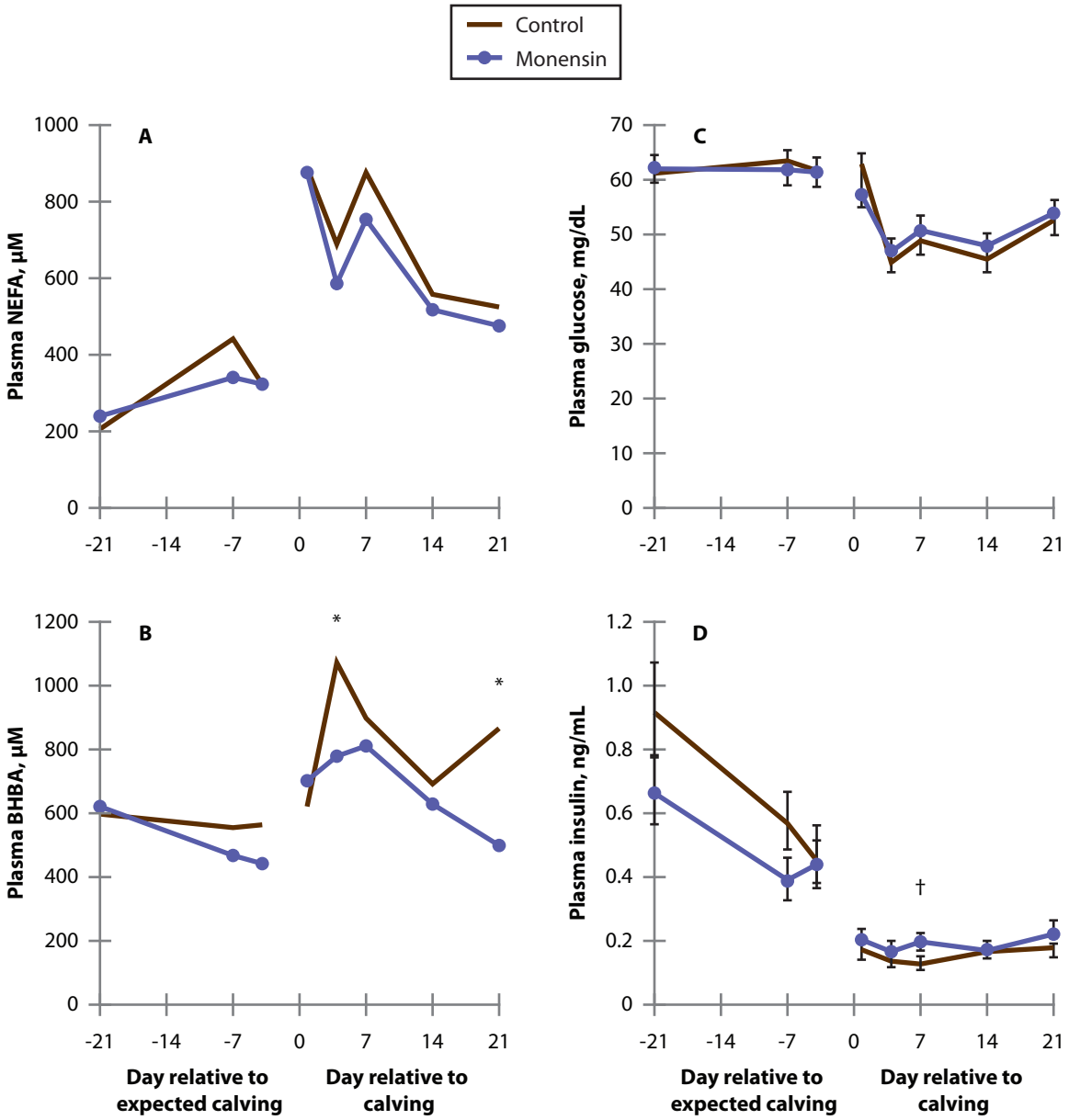

Figure 2. Plasma concentrations of nonesterified fatty acids (A), beta-hydroxybutyrate (B), glucose (C), and insulin (D) during the experimental period.

A. No treatment effects were detected, but there was a day effect ($P < 0.001$; SEM = 84.9). B. A treatment by day interaction ($P < 0.01$) was detected (SEM = 73.6; *$P < 0.05$). C. No treatment effects were detected — only a day effect ($P < 0.001$; SEM = 2.38). D. Significant effects of day ($P < 0.001$) and day by treatment interaction ($P < 0.05$) were detected. Cows receiving monensin tended ($P < 0.10$) to have greater plasma insulin concentrations on day 7 postpartum. SEM are shown in D (†$P < 0.10$).