METABOLIC CHANGES DURING THE TRANSITION PERIOD

A. F. Park, J. E. Shirley, E. C. Titgemeyer, R. C. Cochran, J. M. DeFrain, E. E. Ferdinand, and D. E. Johnson [1]

Summary

We used four ruminally fistulated, multiparous, pregnant Holstein cows to measure changes in concentrations of plasma metabolite as the dairy cow transitions from one lactation to the next. Diets consisted of typical far-off and close-up diets, a late lactation diet containing wet corn gluten feed (20% DM), and an alfalfa hay-corn silage based early lactation diet. Calculated NE_L (Mcal/lb), measured crude protein (%), and diet digestibilities (%; based on steers fed at 2% of BW) were 0.78, 18.7, 74.1; 0.70, 11.5, 66.2; 0.74, 15.6, 71.0; 0.73, 18.4, 70.7 for late lactation, far-off dry, close-up dry, and early lactation diets, respectively. Blood samples were obtained on day 79 prior to calving and weekly thereafter until calving and on days 1, 3, 5, 7, 15, 20, 25, 30, 60, and 90 after calving. Cows gained body weight and condition during the dry period, peaked just prior to calving, and lost weight and condition steadily through the first 11 weeks of lactation. Calculated energy balance was negative during the first 3 weeks of lactation. Plasma concentrations of non-esterified fatty acids (NEFA), glucose, and insulin to glucagon ratio remained fairly stable during the dry period. Plasma glucose increased just before calving, decreased markedly during early lactation, then increased and stabilized by day 30 of lactation. Plasma NEFA concentrations increased at calving and were elevated during early lactation, then returned to prepartum concentrations by day 30 of lactation. The insulin to glucagon ratio decreased just prior to calving, continued to decrease until day 7 of lactation, and then remained stable until the end of the trial. Changes in diet and intake affected plasma urea nitrogen, which decreased as dietary protein decreased during the far-off period, decreased with intake during the close-up period, and increased after calving consistent with the higher dietary protein and increase in dry matter intake. Most of the observed metabolic adaptations reflected the energy status of the cow with large shifts occurring around parturition. Certainly, some of the hormones associated with calving can initiate metabolic events favorable to lactation, but the changes in energy balance and nutrient supply support the continued diversion of nutrients to the mammary gland. These data support the concept that dairy cows experience a period of increased tissue mobilization from approximately 2 days prior to calving until 30 days after calving. In conclusion, a number of metabolic adaptations occur in transition dairy cows that provide clues to improve feeding and management guidelines.

(Key Words: Transition, Dairy Cow, Plasma.)

Introduction

As dairy cows transition from one lactation through the dry period to the next lactation their metabolism changes to accommodate the shift in nutrient and physiological requirements. The requirements of the developing fetus and maintenance of body tissues dictate the requirements of the far-off dry cow. Cows entering the dry period with a body condition score

[1]Department of Statistics.

(BCS; 1 = thin and 5 = fat) of less than 3 require additional nutrients to increase body stores, and young cows require additional nutrients for growth. The requirements of close-up cows are greater than those of the far-off cow because the fetus is in a rapid growth phase and mammary gland function (lactogenesis) is initiated in preparation for lactation. Typically, feed intake decreases sharply (20 to 30%) during the last week before calving followed by a shift in adipose tissue metabolism from deposition to mobilization of fat. Several hormones associated with parturition stimulate and/or depress body metabolic activities in order to deliver the calf and support the lactating mammary gland. Several studies have described metabolic activities during the periparturient period, but none describe the metabolic transitions from one lactation through the dry period and into the first third of the next lactation. Thus, our objective was to characterize the metabolic adaptations that occur when dairy cows transition from one lactation through the first 13 weeks of the next lactation.

Procedures

We used four ruminally fistulated, multiparous, pregnant Holstein cows fed total mixed rations (TMR) twice daily. Typical dairy diets were used for late lactation, far-off, close-up, and lactation (Tables 1 and 2). Plasma samples were collected prior to calving on days 79, 72, 65 (late lactation); days 58, 51, 44, 37, 30 (far-off); days 23, 16, 9, 2 (close-up); and then days 1, 3, 5, 7, 15, 20, 25, 30, 60, and 90 days after calving. Samples were collected from the coccygeal vein between 2 to 3 hours after the AM feeding. Plasma was harvested and stored frozen until analyzed for concentrations of insulin, glucagon, glucose, NEFA, and urea nitrogen. Body weights and BCS were measured weekly to estimate energy balance. Energy balance was defined as net energy of lactation intake minus net energy used for maintenance plus either fetal growth or lactation.

Results and Discussion

All cows calved within an 8-day period, and none experienced health disorders. Thus, metabolic profiles reflect normal cows transitioning from one lactation to the next. All cows received a diet consistent with their state of lactation or gestation (Tables 1 and 2).

Cows gained body weight and condition from dry off to calving with increases in body weight from 1295 lb to 1446 lb and body condition from 2.7 to 2.9 (Figure 1). Prepartum gains in body weight and condition correlated well with calculated energy balance (Figure 2). However, postpartum losses in body weight and condition do not correlate well with calculated energy balance likely due to an overestimation of the net energy of lactation value of the diet consumed.

The insulin to glucagon ratio began to decrease by day 2 prior to calving, continued to decrease until day 5 after calving, then remaining low, but stable, for the remainder of the trial (Figure 3). Plasma glucose concentration increased sharply on day 2 prior to calving, reflective of the declining insulin to glucagon ratio, then decreased across calving before rebounding with intake by day 30 after calving (Figure 4). Concentrations of NEFA's, reflecting fat mobilization from adipose tissue, began to increase 2 days prior to calving, peaked on day 15 postpartum, and returned to prepartum concentrations by day 30 after calving (Figure 5). Plasma urea nitrogen concentration decreased during the far-off period and increased initially when cows were fed the close-up diet (Figure 6) containing 15.6% CP. Likely the decrease in PUN concentrations during the far-off period were due to a lower dietary protein content (11.5% CP). Plasma urea nitrogen concentrations decreased during the close-up period and then increased dramatically after calving. Decreasing PUN concentrations during the close-up period mirrored the decrease in feed intake during this time. Concentrations increased sharply after calving with an increase in dietary protein, dry matter intake, and tissue mobilization to support lactation.

The majority of observed metabolic adaptations reflected the energy status of the cow with the major shifts associated with parturition and onset of lactation. Certainly, some of the hormones associated with calving can initiate metabolic events favorable to lactation, but the changes in energy balance and nutrient supply support the continued diversion of nutrients to the mammary gland. These data support the concept that dairy cows experience a period of increased tissue mobilization from approximately 2 days prior to calving until 30 days after calving. In conclusion, a number of metabolic adaptations occur in the transition dairy cow, and they could provide clues that will improve feeding and management guidelines.

Table 1. Experimental Diets

	Diets (% of DM)			
Ingredient	Late Lactation	Far-off	Close-up	Lactation
Alfalfa hay	20.0	–	15.0	30.0
Prairie hay	–	48.4	20.0	–
Corn silage	10.1	19.8	30.0	15.0
Corn grain	27.7	22.4	18.7	32.0
Whole cottonseed	9.3	–	–	9.3
Fishmeal	1.3	–	–	1.3
Expeller soybean meal	7.7	–	9.4	3.3
48% soybean meal	–	8.4	4.4	4.4
Wet corn gluten feed	19.6	–	–	–
Molasses	1.3	–	–	1.0
Limestone	1.38	0.06	0.60	1.36
Dicalcium phosphate	0.05	0.40	0.74	0.88
Sodium bicarbonate	0.68	–	–	0.75
Trace mineral salt[1]	0.29	0.34	0.50	0.32
Magnesium oxide	0.20	–	0.50	0.21
Vitamin A,D,E[2]	0.12	0.11	0.12	0.13
Sodium selenite premix[3]	0.08	0.02	0.04	0.01

[1]Composition: not less than 95.5% NaCl, 0.24% Mn, 0.24% Fe, 0.05% Mg, 0.032% Cu, 0.032% Zn, 0.007% I, and 0.004% Co.
[2]Contributed 4,912 IU vitamin A, 2,358 IU vitamin D, and 24 IU vitamin E per kg diet DM.
[3]Contributed 0.06 mg Se per kg diet DM.

Table 2. Chemical Characteristics of Experimental Diets

	Diets (% DM)			
Nutrient	Late Lactation	Far-off	Close-up	Lactation
Dry matter, %	75.3	82.5	76.9	82.5
Crude protein, %	18.7	11.5	15.6	18.4
Soluble protein, % of CP[1]	31.3	25.2	25.2	31.3
RDP, % of CP	62.1	63.4	65.8	63.4
ADF, %	17.5	25.2	22.0	18.2
NDF, %	29.9	42.9	34.4	27.0
Non-fiber carbohydrate, %	37.8	35.2	39.1	40.4
TDN, %	73.2	67.0	69.1	72.3
NE_L , Mcal/kg[2]	0.78	0.70	0.74	0.73
Crude fat, %	5.75	3.76	3.49	5.60
Ash, %	7.70	6.72	7.40	8.43
Calcium, %	1.07	0.52	0.81	1.51
Phosphorus, %	0.66	0.36	0.49	0.71
Magnesium, %	0.34	0.20	0.35	0.33
Potassium, %	1.41	1.15	1.49	1.48
Sodium, %	0.37	0.11	0.17	0.33
Sulfur, %	0.25	0.13	0.17	0.21

[1]Based on feed analysis from Dairy Herd Improvement Forage Testing Laboratory (Ithaca, NY).

[2]Calculated based on NRC (2001). Estimates of NE_L values from summation of individual ingredients (0.78, 0.66, 0.71, and 0.77 for the late lactation, far-off, close-up, and lactation diets, respectively).

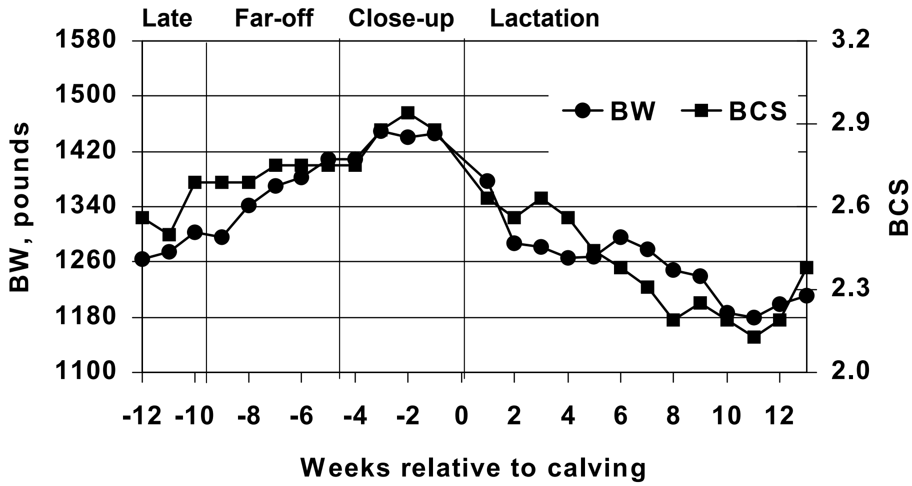

Figure 1. Body Weights and Body Condition Scores.

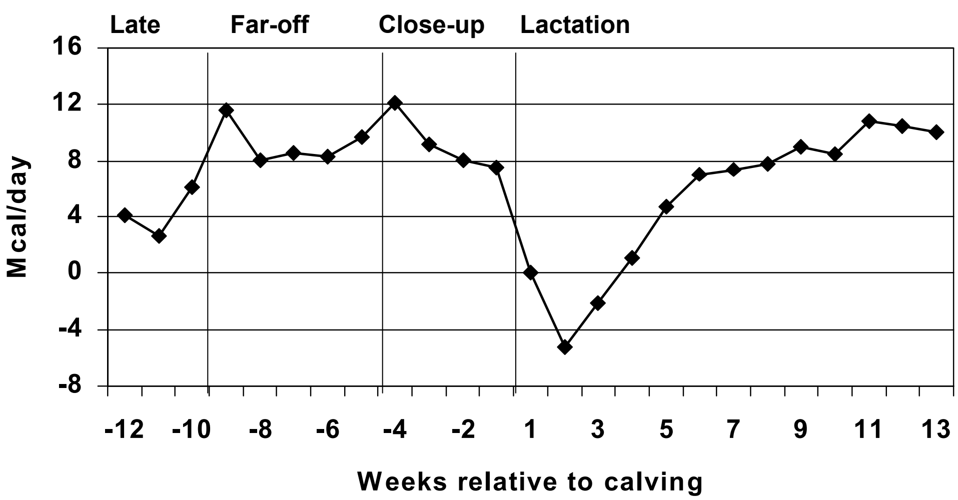

Figure 2. Calculated Energy Balance.

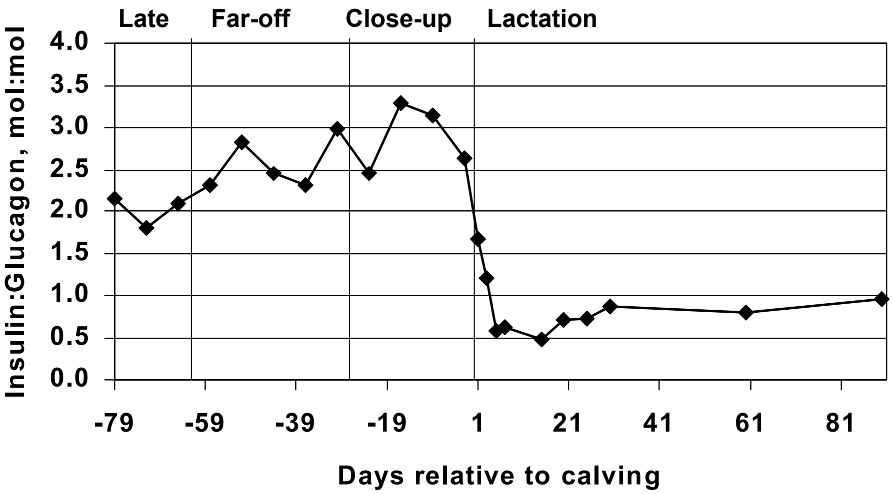

Figure 3. Molar Ratio of Insulin to Glucagon.

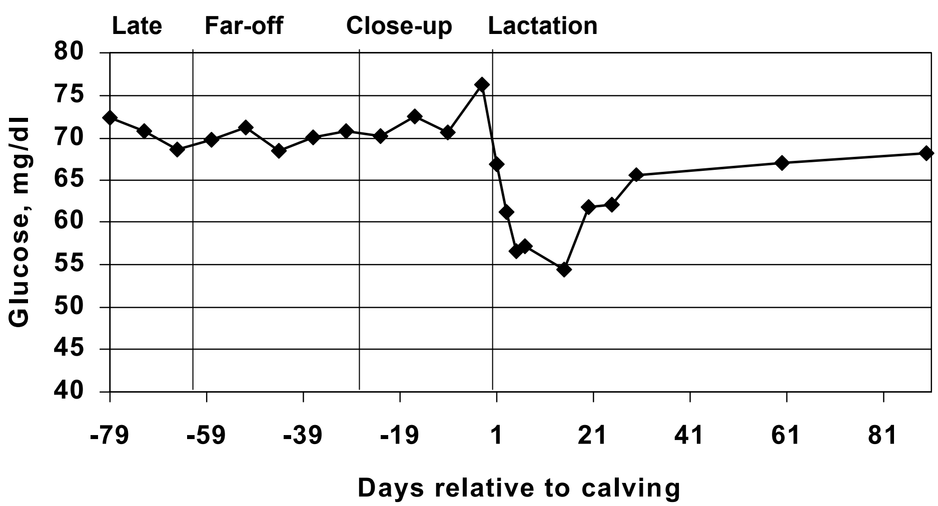

Figure 4. Concentrations of Plasma Glucose.

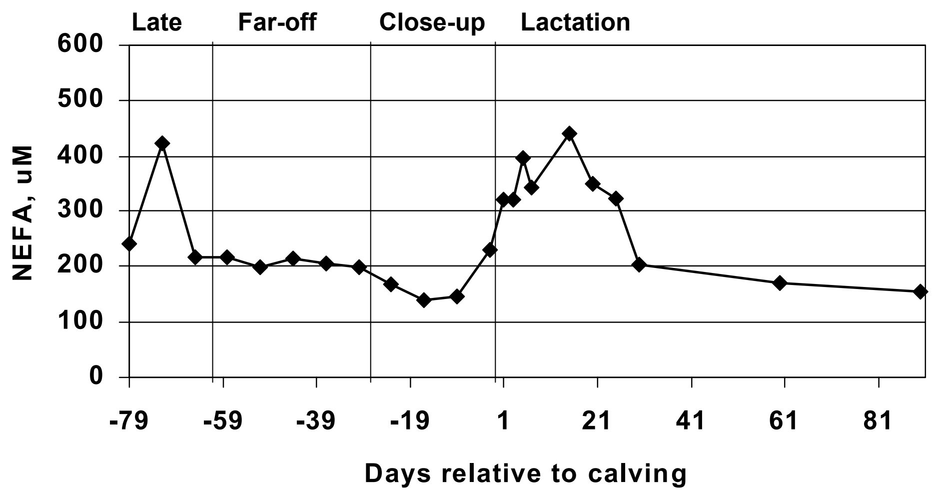

Figure 5. Concentrations of Plasma Nonesterified Fatty Acids (NEFA).

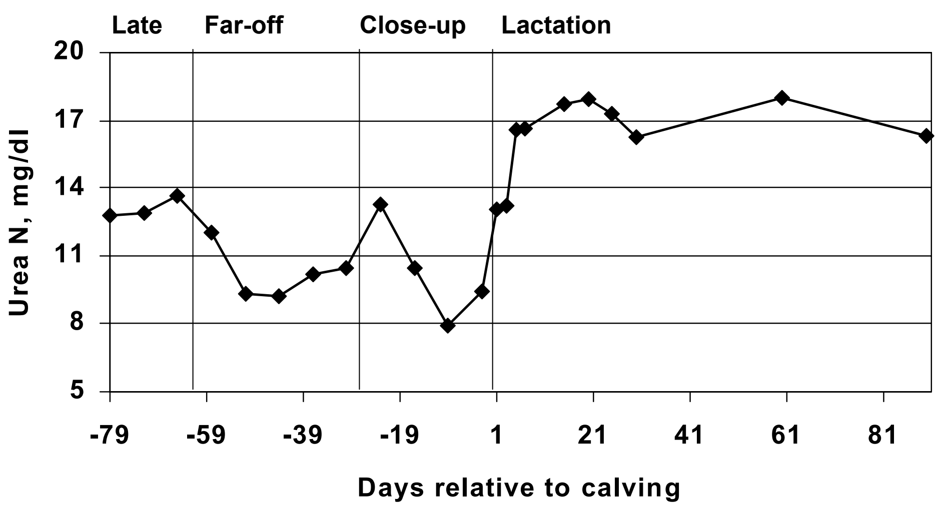

Figure 6. Concentrations of Plasma Urea Nitrogen (PUN).