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Characteristic changes of ruminal fermentation in transition dairy cows

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CHARACTERISTIC CHANGES OF RUMINAL FERMENTATION IN TRANSITION DAIRY COWS

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Summary

Four-ruminally fistulated, multiparous, pregnant Holstein cows were used to delineate changes in ruminal fermentation in dairy cows as they experienced the transition 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. Ruminal measurements were taken on days 72 (late lactation), 51 (far-off), 23, and 9 (close-up dry) before calving and on days 6, 20, 34, 48, 62, 76, and 90 days after calving. Ruminal samples were collected at hours 0, 3, 6, 9, and 12 after feeding on each sampling date. Major shifts in ruminal fermentations occurred when the close-up diet was consumed before calving and in concert with an increase in DM intake during the first 48 days of lactation. Dry matter digestibility increased after cows were switched to the close-up diet and continued this trend through day 6 postpartum. Ruminal pH decreased and total volatile fatty acids, peptides, and free amino acids increased after cows were switched to the early lactation diet. These

data support the concept that alterations in ruminal fermentation reflect changes in both diet and intake.

(Key Words: Transition, Dairy Cow, Rumen Fermentation.)

Introduction

Improving nutritional status of transition cows can help ensure a successful lactation by improving rumen function and reducing the incidence of metabolic diseases. Transition dairy cows face a number of nutritional challenges including diet changes, decreased dry matter intake (DMI), and increased nutrient requirements. The generally observed decrease in prepartum DMI followed by a major diet change immediately after parturition can lead to lactic acidosis, ketosis, milk fever, and displaced abomasal disorder. Recommended transition cow management dictates that dry cows are fed a close-up diet containing a portion of the feedstuffs included in the lactation diet beginning 21 days before the expected calving date. This practice is designed to begin adapting the ruminal microbial population to the lactation diet before it is introduced after parturition. The 21-day duration of the close-up period ensures that all cows are fed the close-up diet for at least 14 days. This program works reasonably well but little information exists regarding its impact on ru-

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men function. Thus, our objective was to characterize ruminal responses to dietary changes from one lactation through the first third of the next lactation in an effort to provide a basis for improving transition cow nutrition.

Procedures

We used four-ruminally fistulated, multiparous, pregnant Holstein cows fed twice daily typical dairy diets for late lactation, far-off and close-up dry, and early lactation. Sample collections were made on days 72 (late lactation), 51 (far-off), 23 and 9 (close-up) and on days 6, 20, 34, 48, 62, 76, and 90 postpartum. Total tract dry matter digestibility (DMD) and solid passage rate were measured using indigestible acid detergent fiber (IADF) as the marker. Calculations of DMD and solid passage rate required determination of IADF concentrations in diet, refusals, digesta, and fecal samples. Digesta and fecal sample collections utilized a total ruminal collection via cannula and fecal grab sampling scheme (every 6 hr for a day then advancing 2 hr until 12 samples were collected). Ruminal fermentative measurements included pH, total volatile fatty acids (TVFA), peptides, free amino acids, and ammonia.

Results and Discussion

Metabolic profiles (companion study) reflected a normal transitioning of cows from one lactation to the next with no health disorders observed during the experiment. All cows received a common diet consistent with their physiological state (Tables 1 and 2). Solid rate of passage increased steadily from late lactation to day 23 prior to calving, whereas DMD remained relatively unchanged (Figure 1). Changes occurred in DMD and solid rate of passage during the last 3 weeks of gestation as DMI decreased (Figure 2). Dry

matter digestibility increased from 50.4% on day 23 prior to calving to 58.3% on day 6 postpartum, whereas solid rate of passage decreased substantially (6.47 to 3.27% per h). Total tract dry matter digestibility and solid rate of passage remained fairly stable between day 6 and day 62 after calving. Solids passage rate decreased from 4.0 to 3.0% per hr and DMD increased 52.1 to 64.1% after d 62 in lactation.

Ruminal pH (Figure 3) increased after cows were switched to the far-off diet and remained elevated until lactation began, likely due to an increase in fiber content of dry cow diets. Ruminal pH decreased (6.7 to 6.1) between day 9 before calving and day 20 after calving as a result of the increased amount of concentrate in the lactation diet and increased DMI. Ruminal pH is important because it influences the microbial population, ruminal digestion, and absorption. Total volatile fatty acid concentrations (Figure 4) remained relatively constant from late lactation to day 9 before calving, then increased until day 48 after calving (93.8 to 153.2 mM), then decreased through day 90. Ruminal TVFA concentrations are a function of production, absorption, and rate of passage. The increase in ruminal TVFA concentration between day 9 and day 48 postpartum mirrored increases in intake and was likely responsible for increased production. The decrease in ruminal TVFA concentrations after d 48 was partially attributed to increased absorption because intake was increasing and solid rate of passage was decreasing.

Ruminal concentrations of individual VFAs are influenced by the type and amount of feedstuffs in the diet. Concentrations of acetate are associated with dietary forages, whereas concentrations of propionate are associated with dietary concentrates. The increase in acetate to propionate ratio observed when cows consumed the far-off and close-up

diets (Figure 5) reflects a decrease in propionate relative to acetate, whereas the decrease in acetate to propionate ratio after day 48 in lactation was due to a decrease in acetate relative to propionate.

Ruminal microbes work in concert to degrade dietary protein and non-protein nitrogen into peptides, free amino acids, and ammonia for incorporation into microbial crude protein. Ruminal peptide concentrations remained unchanged in the dry period but decreased from 2.5 mM on day 48 to 1.1 mM on day 62 postpartum (Figure 6) then remained unchanged. Ruminal free amino acid concentrations (Figure 7) decreased during far-off and close-up

periods and increased after calving. Ruminal ammonia concentrations decreased during the close-up period and remained fairly stable during lactation (Figure 8), except for the sharp increase on day 6 postpartum.

The lower peptide concentration after day 48 of lactation (Figure 6) was attributed to increased microbial activity. Concentrations of free amino acids increased in lactation but were quite variable. The variability of ruminal free amino acids during early lactation possibly reflects microbial adjustments to increases in DMI. These data support the concept that ruminal fermentation is affected by both diet and intake.

Table 1. Experimental Diets

| Ingredient | Diets (% of DM) | | | |
|-------------------------------------|-----------------|---------|----------|-----------|
| | 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 | 0.00 | — | 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 |

¹Composition: 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.

²Contributed 4912 IU vitamin A, 2358 IU vitamin D, and 24 IU vitamin E per kg diet DM.

³Contributed 0.06 mg Se per kg diet DM.

Table 2. Chemical Characteristics of Experimental Diets

| Nutrient | Diets (% DM) | | | |
|--|----------------|---------|----------|-----------|
| | 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/lb 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 |

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

²Calculated 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).

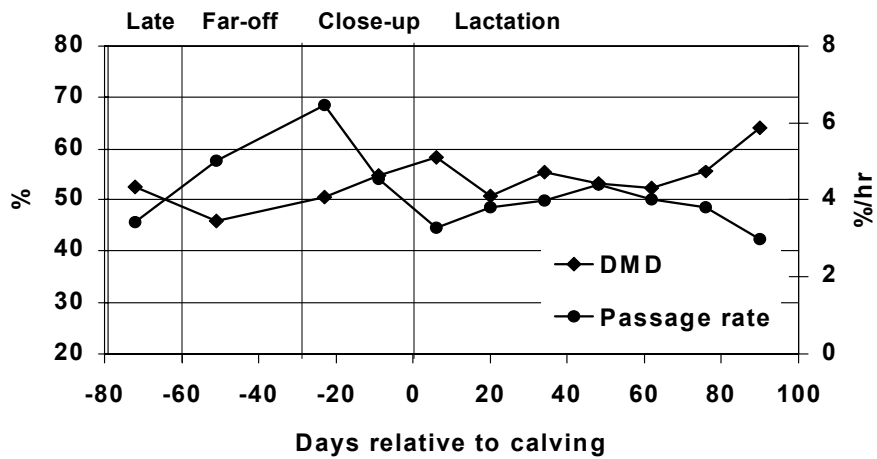


Figure 1. Dry Matter Digestibility and Rate of Passage.

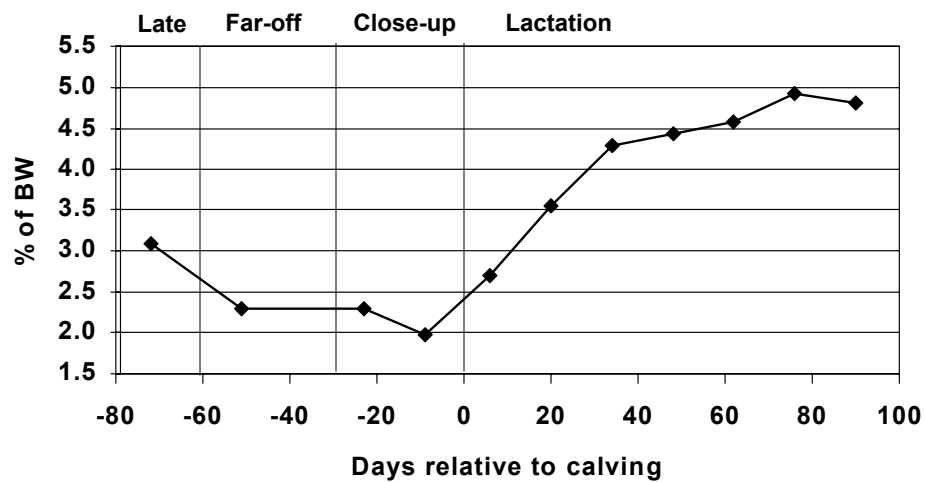


Figure 2. DMI as a Percentage of Body Weight (BW).

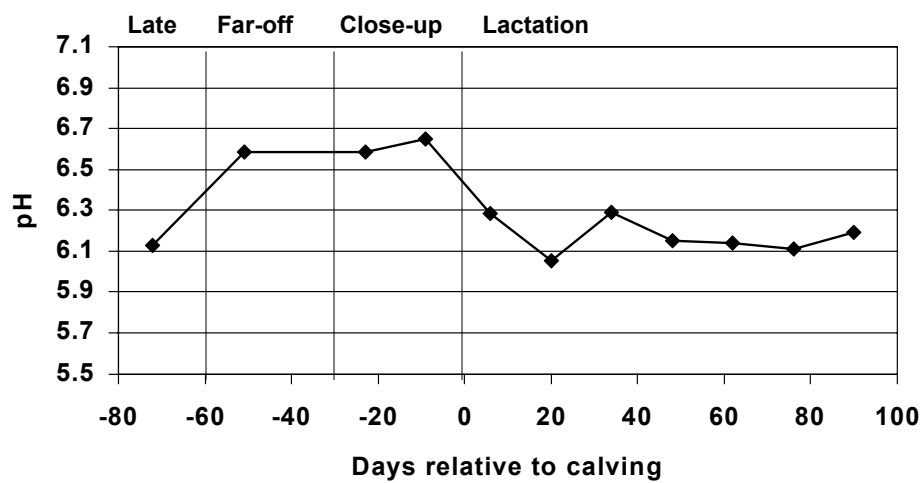


Figure 3. Ruminal pH.

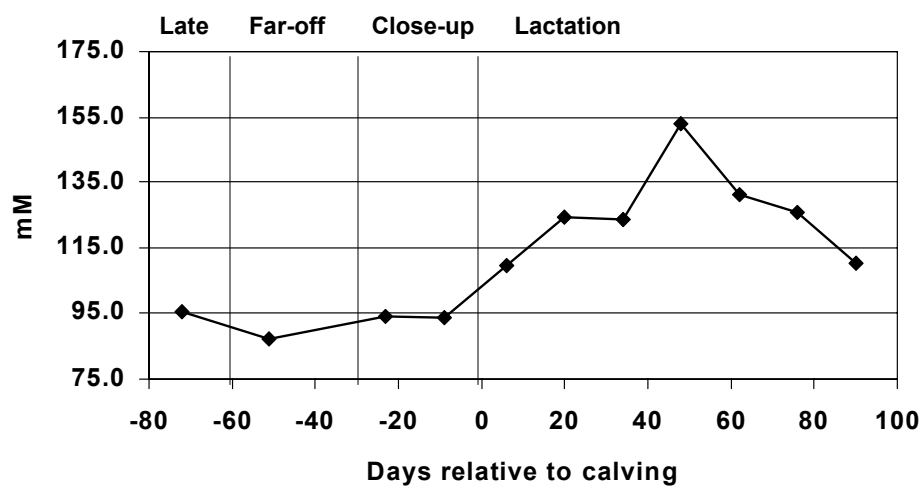


Figure 4. Total VFA.

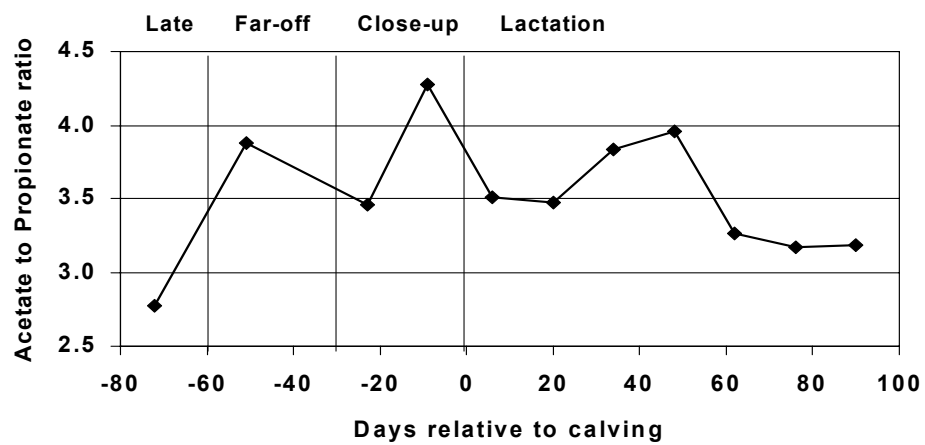


Figure 5. Ratio of Acetate to Propionate.

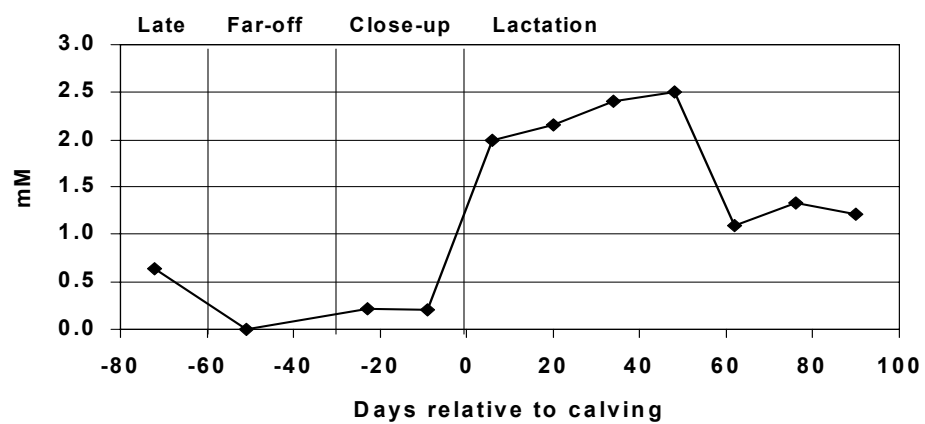


Figure 6. Ruminal Peptide Concentration.

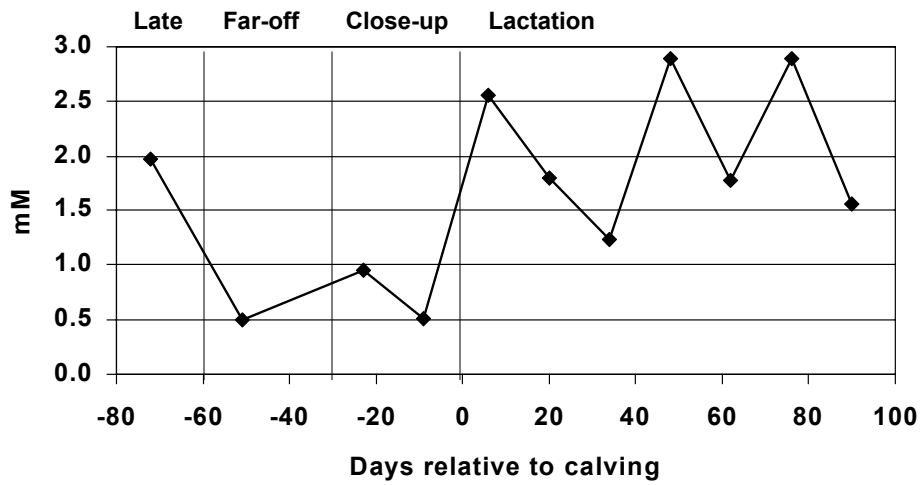


Figure 7. Ruminal Free Amino Acid Concentration.

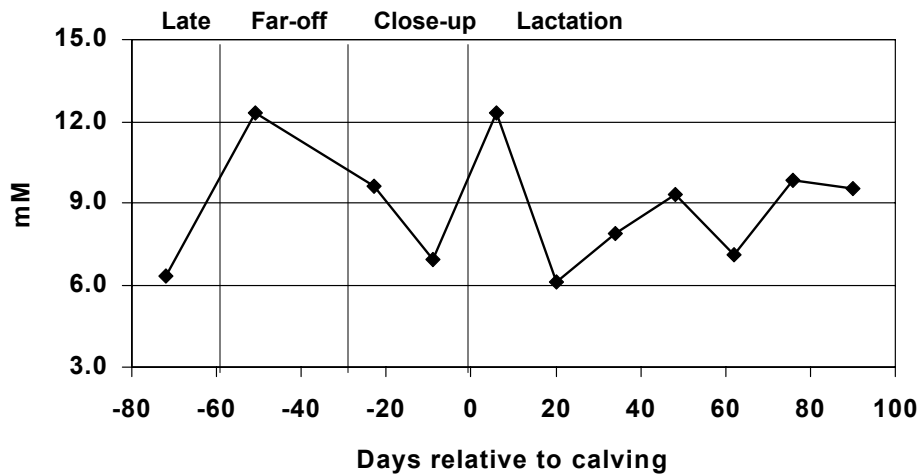


Figure 8. Ruminal Ammonia Concentration.