Optimizing the Transition Cow Management System on Commercial Dairy Farms

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Introduction

Nutrition and management of the transition cow continues to attract substantial research attention. Despite the tremendous quantity of research conducted on nutrition and physiology of transition cows, the transition period remains a problematic area on many commercial dairy farms, and metabolic disorders continue to occur at economically important rates (Burhans et al., 2003). Data recently summarized by researchers at the University of Minnesota (Godden et al., 2003) indicate that approximately 25% of cows that left dairy herds in Minnesota from 1996 through 2001 did so during the first 60 DIM, with an uncertain additional percentage leaving by the end of the lactation as an end result of difficulty during the transition period. The economic ramifications of these “broken cows” together with the comprehensive costs associated with occurrence of the various metabolic disorders in both clinical and subclinical form are large. Therefore research attention will continue to focus on understanding the biology of transition cows and implementing management schemes on dairy farms to optimize production and profitability on these farms.

Substantial research attention has focused during the past ten to fifteen years on understanding the physiological adaptations underpinning the transition to lactation and developing nutritional strategies to foster transition period success. Recent information has caused the dairy industry to rethink the length of the dry period, which potentially has carryover effects for how nutritional systems are implemented for transition cows on commercial dairy farms. The purpose of this paper will be to briefly overview the physiological changes that must occur successfully and the nutritional management strategies that will promote such success, and then to review recent information on the dynamics of dry matter intake in transition cows, concluding with methods to actualize the transition cow management system on commercial dairy farms.

Physiological Adaptations of Transition Cows

For cows to successfully transition to lactation, metabolic adaptations that enable increased synthesis of glucose, mobilization of sufficient (but not excessive) body fat reserves to meet the energetic demands of lactation, and calcium mobilization to meet the increased demands for calcium. The adaptations that must occur in the dairy cow to successfully adapt to increased demand for calcium have been reviewed in detail (Goff and Horst, 1997). From an energy metabolism standpoint, the need to synthesize and

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direct glucose to the mammary gland for synthesis of lactose represents the overriding metabolic demand during the first few weeks of lactation. The cow accomplishes this by concurrently increasing hepatic gluconeogenesis (Reynolds et al., 2003) and decreasing oxidation of glucose by peripheral tissues (Bennink et al., 1972). Reynolds et al. (2003) recently reported that there was little net use or release of glucose by the gastrointestinal tract during the transition period and early lactation; therefore, the 267% increase in total glucose output by the gastrointestinal tract and liver from 9 d before expected parturition to 21 d after parturition resulted almost completely from increased hepatic gluconeogenesis (Figure 1). The major substrates for hepatic gluconeogenesis in ruminants are propionate from ruminal fermentation, lactate from Cori cycling, amino acids from amino acid catabolism, and glycerol released during lipolysis of adipose tissue (Seal and Reynolds, 1993). The calculated maximal contribution of propionate to net glucose release by liver ranged from approximately 50 to 60% during the transition period; that for lactate ranged from 15 to 20%; and that for glycerol ranged from 2 to 4% (Reynolds et al., 2003). By difference, amino acids accounted for a minimum of approximately 20 to 30% during the transition period; the maximal contribution of alanine increased from 2.3% at 9 d prepartum to 5.5% at 11 d postpartum. These data are consistent with those of Overton et al. (1998), who reported that hepatic capacity to convert [1-^{14}C]alanine to glucose was approximately doubled on 1 d postpartum compared with 21 d prepartum.

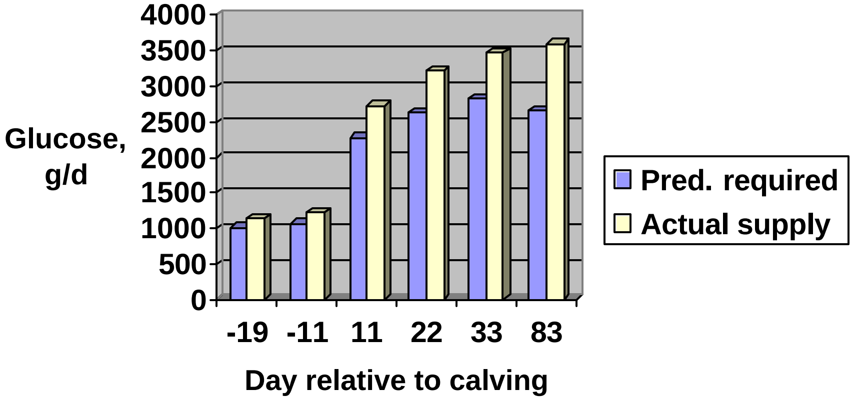
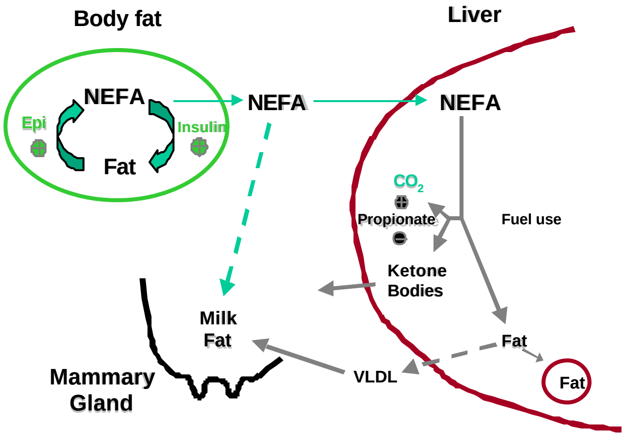


Figure 1. Predicted whole-body glucose requirements compared with actual supply of glucose by gut and liver during the transition period and early lactation. Data are from Reynolds et al. (2003). Predictions are as described by Overton (1998).

A second key metabolic adaptation relates to mobilization of body reserves, particularly body fat stores, in support of the increased energetic demands during early lactation paired with insufficient energy intake. This mobilization of body fat occurs through release of NEFA into the bloodstream (Figure 2). These NEFA are used for energy by body tissues and as precursors for synthesis of milk fat; however, available data suggest that the liver takes up NEFA in proportion to their supply (Emery et al., 1992). Unfortunately, the liver typically does not have sufficient capacity to completely dispose of NEFA through export into the blood or catabolism for energy (Figure 2), and thus transition cows are predisposed to accumulate triglycerides in the liver tissue. The primary consequence of this triglyceride accumulation appears to be impaired liver function, including decreased capacity for ureagenesis and gluconeogenesis.



Adapted from Drackley, 1999

Figure 2. Schematic of metabolism of nonesterified fatty acids (NEFA) in the dairy cow (adapted from Drackley, 1999).

Nutritional Strategies to Support Physiological Adaptations

The primary goal of nutritional management strategies during the transition period should be to support the various physiological changes, including those for glucose metabolism. Industry-standard nutritional management of dairy cows during the dry period consists of a two-group nutritional scheme. The Dairy NRC committee (2001) recommended that a diet containing approximately 0.57 Mcal/lb of NE_L be fed from dry off until approximately 21 d before calving and that a diet containing 0.70 to 0.73 Mcal/lb of NE_L be fed during the last three weeks preceding parturition. The primary rationale for feeding a lower energy diet during the early dry period is to minimize body condition score gain during the dry period. Recent data (Dann et al., 2003) specifically detail potential detrimental carryover effects during early lactation of supplying excessive energy to dairy cows during the early dry period. In general, available data support feeding the higher energy diet for two to three weeks prior to parturition (Contreras et al., 2002; Corbett, 2002; Mashek and Beede, 2001). Furthermore, recent data (Contreras et al., 2002) support managing cows to achieve a body condition score of approximately 3.0 at dry off rather than the traditional 3.5 to 3.75 body condition score. This is perhaps partially due to the decreased DMI as body condition score increases during the prepartum period (Hayirli et al., 2002).

Carbohydrate nutrition

Because of the focus on increasing energy content of the diet fed during the close-up period, most of the research focusing on increasing the energy content of the close-up diet has related to varying the nonfiber carbohydrate (NFC) content of the diet. A commonly held notion in the dairy industry is that diets higher in NFC content than traditional dry cow diets must be fed prior to calving in order to promote the development of ruminal papillae for adequate absorption of VFA produced during ruminal fermentation. This notion was based on one experiment in which dry cows were adapted from a diet containing a large amount of poor quality forage to a diet containing a much larger proportion of grain (Dirksen et al., 1985). However, Andersen et al. (1999) reported that transition cows subjected to dietary changes much more typical of those in modern nutritional management systems did not have meaningful changes in ruminal epithelia during the transition period. Regardless of the effect on rumen epithelia, feeding diets containing higher proportions of NFC should promote ruminal microbial adaptation to NFC levels typical of diets fed during lactation and provide increased amounts of propionate to support hepatic gluconeogenesis and microbial protein (providing the diet contains sufficient ruminally degradable protein) to support protein requirements for maintenance, pregnancy, and mammogenesis.

Several investigators have examined the effects of NFC level in the close-up diet on metabolism and performance, and results from seven experiments conducted during the past ten years to specifically examine this question are summarized in Table 1. Although the range of NFC concentrations investigated in these experiments was very large, when paired with a low NFC diet, feeding a high NFC diet virtually always resulted in higher prepartum DMI and frequently resulted in one or more positive effects on energy metabolism or production (Table 1).

Table 1. Effect of NFC[1] concentration in the prepartum diet on metabolism and performance.

	NFC, % of DM		
Experiment	Low	High	Effect of high NFC
Grum et al., 1996	18	28	↑ pre-DMI; ↑ pre-insulin
Minor et al., 1998	24	44	↑ pre-DMI; ↑ milk yield[2]
Mashek and Beede, 2000	35	38	↓ pre-BHBA; ↑ pre-insulin; ↑ milk yield[3]
Keady et al., 2001	13	28	↑ pre-DMI
Holcomb et al., 2001	25	30	↑ pre-DMI; ↓ peri-NEFA
Doepel et al., 2002	24	30	↑ post-DMI; ↓ peri-NEFA; ↓ liver TG[4]
Rabelo et al., 2003	38	45	↑ pre-DMI; ↑ post-DMI[4] (d 1 to 20)

[1] Nonfiber carbohydrate; 100 – [(NDF-NDICP) + CP + EE + Ash]; NRC, 2001

[2] Cows fed higher NFC prepartum continued on higher NFC diet postpartum

[3] Higher NFC increased milk yield only in 3rd lactation and greater cows

[4] Statistical trend.

Considerable research has investigated the effects of replacing forages in dairy rations with nonforage fiber sources (NFFS; i.e., beet pulp, citrus pulp, soybean hulls, cottonseed, wheat midds, etc.). As an example, Pickett et al. (2003) replaced forage in a conventional dry cow diet with NFFS; cows fed the diet containing NFFS had increased prepartum DMI and decreased prepartum NEFA concentrations in plasma. Anecdotal reports have suggested that, instead of replacing forage, replacing NFC sources with NFFS may promote DMI in cows during the prepartum period. Smith et al. (2002) compared feeding two high energy diets based upon different carbohydrate sources during the prepartum period. The high NFC diet contained 0.72 Mcal/lb of NE_L, 40% NFC, and 28% starch; the high NFFS diet contained 0.70 Mcal/lb of NE_L, 34% NFC, and 18% starch. Carbohydrate source in the prepartum diet in this experiment did not affect peripartal DMI, postpartum milk yield, or peripartal concentrations of NEFA and BHBA in plasma and liver composition. Although the advantages of the high NFFS diet relative to the high NFC diet were not readily apparent, it is interesting to note that this study is one of the few reports available whereby feeding a diet higher in NFC during the prepartum period did not result in beneficial effects relative to a lower NFC diet prepartum.

In summary, available data do not clearly support a single strategy for approaching carbohydrate nutrition of transition cows during the prepartum period. However, most studies report one or more positive outcomes when higher NFC diets are fed relative to a paired lower NFC control diet. This conclusion is consistent with the data of Hayirli et al. (2002) who reported that prepartum DMI was positively correlated with NFC content of the prepartum diet. The only guideline provided by the Dairy NRC (2001) for carbohydrate nutrition of dry cows was that NFC content of the close-up diet should not exceed 43% of diet DM. This recommendation is consistent with data indicating that feeding diets during the close-up period containing high concentrations of NFC (43 to 45%) appeared to accentuate the decrease in DMI occurring in the days preceding parturition (Minor et al., 1998; Rabelo et al., 2003). Overall, the data summarized above support feeding diets during the close-up period that contain moderately high concentrations (34 to 36%) of starch-based NFC sources.

Protein considerations

The 2001 Dairy NRC abandoned the crude protein (CP) system in favor of the metabolizable protein (MP) system for predicting protein adequacy of diets fed to dairy cows. In theory, this change was a significant advancement because the MP system is based on predicting how much protein is actually available for the cow to use, whereas the old CP system was based solely on feed composition. The new MP system should replace some of the “art” of ration formulation with science by helping nutritionists account for potential changes in rumen fermentation patterns when feeds change or new diets are instituted. We recommend formulating closeup diets to provide approximately 1100 to 1200 grams per day of MP (based on group intake of 24 to 26 lbs of dry matter). For comparison, if diet NFC concentrations range from 34 to 36% as recommended above, this amount of MP can be met by feeding a diet containing approximately 13 to 15% CP under the old system; feeding closeup diets containing more than 15% CP is not advantageous and may be detrimental based upon inefficient usage of excess CP. Research from our group (Piepenbrink et al., 2001) among others has indicated that dietary guidelines for amino acid nutrition of transition cows should be similar to those established for lactating cows (i.e., 2.2% of MP supply for methionine and 6.6% of MP supply for lysine).

Macromineral considerations

Most of the research conducted on macromineral nutrition of closeup cows has focused on prevention of milk fever and related disorders. The authors of the 2001 Dairy NRC effectively discounted the potential of practically feeding closeup diets sufficiently low in calcium to prevent hypocalcemia and focused attention instead on the approach of adjusting the dietary cation-anion difference (DCAD) of the closeup diet to facilitate mobilization of calcium from bone to support the increased need for calcium at calving. In general, the DCAD of closeup diets is adjusted by first lowering the potassium and sodium content of the prepartum diet to less than 1.3 and 0.15% of the diet dry matter, respectively. Then, sulfur is supplemented up to 0.30 to 0.40% of diet dry matter and chloride is supplemented to the diet until urine pH decreases to between 6 and 7. If dietary constraints dictate that higher levels of potassium or sodium must be fed, then higher levels of sulfur and chloride will need to be fed for effective results. General considerations for implementation of DCAD programs are that DMI sometimes is decreased when these types of diets are implemented and therefore other nutrient levels in the diet may need to be adjusted accordingly, first-calf heifers are not as susceptible to milk fever as mature cows and therefore are not likely to benefit from DCAD closeup programs, and that routine monitoring of urine pH must be conducted to ensure that the amount of the DCAD supplement included in the diet is increased or decreased to maintain urine pH between 6 and 7. Many producers in the Northeast and Upper Midwest have successfully managed milk fever in dairy herds by implementing a partial-DCAD approach – that is, they form the basis of the closeup dry cow ration with forages that are typically low in potassium (i.e., corn silage, grass-based silage or hay) in order to decrease potassium content of the closeup diet to less than 1.3% of diet dry matter. This usually prevents milk fever without incurring the cost of a DCAD supplement or having to increase the complexity of management to ensure success of the full DCAD approach. More uncertain, and difficult to assess on commercial dairy farms, is the success of the partial-DCAD approach in preventing subclinical hypocalcemia.

Dynamics of Dry Matter Intake in Transition Cows

One other area that has received attention recently and that relates practically to carbohydrate composition of the diet fed during the prepartum period in particular is the dynamics of DMI in transition cows. Controlled experiments have shown repeatedly that cows fed for ad libitum intake during the close-up period decrease their voluntary DMI beginning approximately ten days before expected calving, with the extent of decrease from d 21 prepartum to d 1 prepartum on the order of 30%. Grummer (1995) summarized data from several experiments conducted in his laboratory and reported that DMI on d 21 postpartum was correlated with DMI on d 1 prepartum. This led many investigators to focus on elucidating factors affecting DMI of dairy cows during the close-up period. Hayirli et al. (2002) summarized animal and dietary factors accounting for variation in DMI during the close-up period from a large dataset from studies conducted at several universities. Not surprisingly, as prepartum body condition score of cows increased, prepartum DMI decreased. Although DMI as a percentage of BW was comparable for cows averaging a 2.8 or 3.6 body condition score, cows with an average body condition score of 4.4 had a pronounced decrease in prepartum DMI.

Despite the widely held concept that increased total DMI during the close-up period is a harbinger of increased DMI during the postpartum period and overall transition cow success (Grummer, 1995; Hayirli et al., 2002), a growing body of evidence supports the possibility that the shape of the prepartum DMI curve (i.e., the rate and extent of decrease of DMI prior to calving) may be a more meaningful predictor of overall transition health and performance. Recently, Mashek and Grummer (2003) examined the relationships between total DMI from d 21 through d 1 prepartum and the change in DMI between d 21 and d 1 prepartum with postpartum performance and metabolic indices. They reported that postpartum DMI and milk production were more strongly correlated with total prepartum DMI. As total prepartum DMI increased, postpartum DMI and milk yield also increased. However, meaningful metabolic indices (i.e., postpartum plasma NEFA concentrations and liver triglyceride accumulation) were more strongly correlated with the change in DMI from 21 d to 1 d prepartum; as the change in DMI decreased, postpartum plasma NEFA and liver triglycerides also decreased.

The effect of the magnitude of decreased prepartum DMI has been studied in vivo by investigators seeking to determine the potential to restrict energy intake of dry cows in order to perhaps precondition metabolism to negative energy balance. Across several experiments, cows fed balanced prepartum diets restricted to below calculated energy requirements (usually about 80% of predicted requirements) did not decrease DMI during the days preceding parturition. These animals increased their postpartum DMI and milk yield at faster rates than cows consuming the same diets for ad libitum intake (Douglas et al., 1998; Holcomb et al., 2001; Agenas et al., 2003). Furthermore, feed-restricted cows had greater insulin sensitivity (Holtenius et al., 2003) and typically had blunted peripartal NEFA curves compared with those fed for ad libitum intake (Douglas et al., 1998; Holcomb et al., 2001; Holtenius et al., 2003).

Collectively these data are intriguing, but all experiments were conducted with cows that were individually housed and fed. Achieving uniform restricted intake in the typical group-fed situation on commercial farms where social interactions and competition will predominate will be difficult to achieve. Simple replacement of forage with straw in an effort to provide a more bulky diet decreased insulin concentrations (Rabelo et al., 2003) and may not allow for comparable microbial adaptation to a higher energy diet during the prepartum period. Despite these findings, anecdotal reports from the dairy industry have indicated transition success in response to feeding a diet containing large amounts of chopped straw (i.e., 8 to 10 lbs of DM) when this type of diet was fed to a herd experiencing a relatively high incidence of postpartum displaced abomasum. The advantages of such a diet are that straw typically is low in potassium, which should mitigate the risk of hypocalcemia. The high degree of bulkiness should ensure high rumen fill – thereby decreasing the risk of displaced abomasum and potentially limiting energy intake. The disadvantages of feeding this type of diet are the increased risk of sorting by cows and the relatively higher level of feeding management required in the authors' opinion to ensure consistent intake of a high-bulk diet. Controlled research has not been conducted to determine whether the shape of the prepartum DMI curve is flatter when cows are fed a high-bulk diet, thus mimicking the restricted-fed scenario described above. Furthermore, controlled research has not been conducted to determine whether feeding a high-bulk diet is more advantageous than a well-managed higher NFC diet as recommended above for nutritional management of transition cows.

Shortened Dry Periods and Implications for Transition Cow Management

Several years ago, Dr. Kermit Bachman and colleagues at the University of Florida began challenging the concept of the traditional 50 to 60-day dry period. Studies conducted by this group (summarized in Table 2) and several studies conducted at various universities in the US (Annen et al., 2003; Grummer and Rastani, 2003; Fernandez et al., unpublished data) indicate that subsequent cow performance during the next lactation and metabolism is virtually unaffected by decreasing the length of the dry period to 30 to 40 d, particularly for multiparous cows. This has been an interesting area in which to conduct research because field experience is generating knowledge at least at the pace of university-based research. My current personal recommendation is 40-d dry periods for all cows that continue to produce sufficient quantities of milk to merit continued milking.

Table 2. Summary results from shortened dry period studies conducted by the University of Florida.

Trial	Days Dry	Number of Cows	305Actual (adj) (lbs)	305ME (lbs)
Bachman, 2002	34	15	21602	20117
	57	19	21997	19810
Schairer, 2001	32	10	25650	24268
	61	9	22535	23212
Gulay et al., 2003	31	28	21120	21133
	61	27	21684	21384

(adj)= adjusted for previous lactation milk yield.

Shortening the length of the dry period has obvious implications for how nutritional management systems for transition cows are actualized on commercial dairy farms. In situations in which two-group nutritional systems are unfeasible to implement, it allows for implementation of a more suitable one-group nutritional scheme. As described above, two group nutritional schemes for dry cows in a 60-d dry period scenario are preferred because of both economics and potential negative effects of overfeeding cows during the early dry period. However, in my opinion the moderate NFC (34 to 36%) close-up diet can be fed throughout a 40-d dry period, regardless of DCAD. I do not believe that the far-off group will disappear on most commercial farms because many cows will continue to have dry periods of 50 d or greater; however, it potentially becomes a smaller group. Alternatively, dairy producers can elect to feed a far-off diet from 40 to 20 d before expected parturition and then move cows to a close-up group until parturition.

Summary and Implications

Available data support two-group nutritional strategies for dry cows, with diets containing moderately high concentrations (34 to 36%) of NFC from starch-based sources and formulated to provide 1100 to 1200 grams per day of metabolizable protein fed during the late dry period. Feeding diets containing concentrations of NFC in excess of 38% may increase total prepartum DMI, but may accentuate the rate of decrease in DMI prior to calving, thereby leading to metabolic disorders and periparturient difficulty. Shortened dry periods facilitates adoption of a one-group dry cow nutritional management scheme in some situations, although university-based research and field experience will continue to provide insight into optimal management strategies for these cows.

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