TRANSITION COW PROGRAMS -- MANAGEMENT AND METABOLISM

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SUMMARY

Transition cows must exquisitely coordinate their metabolism to meet tremendous increases in nutrient demand during early lactation, particularly the demand for glucose production by liver. Excessive mobilization of nonesterified fatty acids (NEFA) from body fat during the transition period presents challenges to liver function, including the capacity of liver to produce glucose. Strategies to either reduce the supply of NEFA to the liver or optimize the metabolism of NEFA by liver include maximizing dry matter intake of well-formulated rations, dietary supplementation with choline, or short-term drenching strategies using propylene glycol. Supplementation of other nutrients (methionine analogs and conjugated linoleic acid) has been shown to improve performance during early lactation; however, their mode of action does not appear to be related directly to liver metabolism. Research investigating nutritional grouping strategies for dry cows indicates that the two-group dry cow system is preferred to a one-group dry cow system; however, there may be interactions of grouping system with body condition score on postpartum performance.

INTRODUCTION

The transition period of the lactation cycle in dairy cattle is clearly the most important phase of the lactation cycle because it represents the convergence of productive performance, reproductive performance, and health that directly impacts profitability of the dairy enterprise. At the 2001 Southwest Nutrition Conference, we reviewed the metabolic adaptations related to energy metabolism that must occur in order to allow production of large amounts of glucose by liver to support lactose synthesis (Overton and Piepenbrink, 2001). Furthermore, we characterized the potential to optimize fatty acid metabolism by liver during the transition period and suggested some management and nutritional strategies to "manage metabolism" of nonesterified fatty acids (NEFA) in transition cows. Rather than simply reiterate our points from last year's conference, the purpose of this paper will be to briefly provide the context for the metabolic adaptations that we are attempting to manage, update our knowledge based upon new research, and to provide some practical considerations for transition cow programs.

METABOLIC ADAPTATIONS IN TRANSITION COWS

The primary series of metabolic adaptations that must occur to underpin a successful transition to lactation relates to increased glucose synthesis by liver and decreased glucose oxidation by peripheral tissues at the onset of lactation. Glucose represents an overriding metabolic demand during the transition period because of the requirements of the mammary gland for lactose synthesis. Data in Figure 1 indicate that the predicted whole-body requirement for glucose increases from approximately 1,000 g/d during the late dry period to approximately 2,500 g/d during the first three weeks postcalving. The predicted supply of glucose based upon intake of digestible energy matches well with requirements during the late dry period, but is below predicted requirements during early lactation. The actual supply of glucose measured in this experiment is much greater than the predicted supply, indicating that sources other than those accounted for by digestible energy intake are making contributions to liver glucose output during this timeframe. Recent data (Overton et al., 1998) suggest that at least part of the additional glucose is being synthesized from amino acids during early lactation.

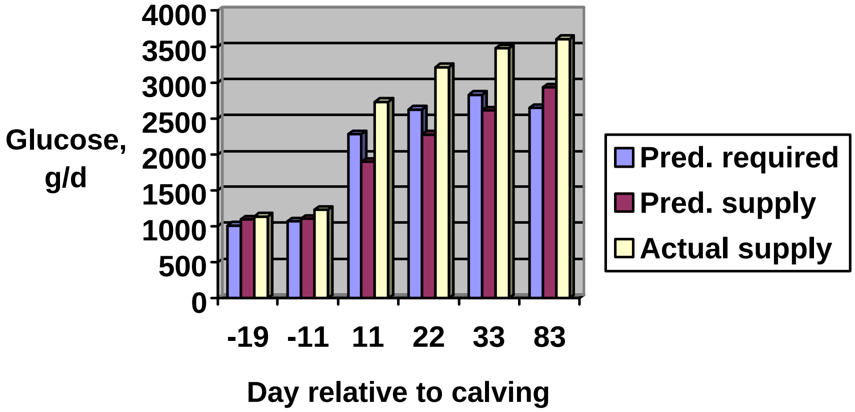

Figure 1. Predicted whole-body glucose requirements compared with predicted and actual supply of glucose by gut and liver during the transition period and early lactation. Data are from Reynolds et al. (2000). Predictions are as described by Overton (1998).

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 3). 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. As we reviewed thoroughly at this conference last year (Overton and Piepenbrink, 2001), the consequence of this triglyceride accumulation appears to be impaired liver function, including decreased capacity for ureagenesis and gluconeogenesis.

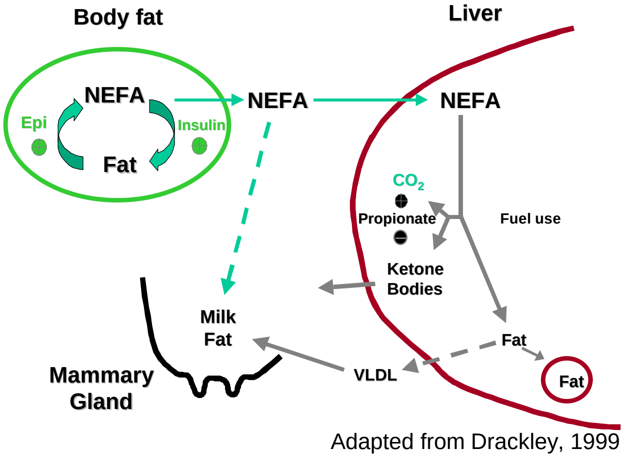

Figure 2. Schematic of metabolism of nonesterified fatty acids (NEFA) in the dairy cow (adapted from Drackley, 1999).

STRATEGIES TO MANAGE LIVER METABOLISM IN TRANSITION COWS

Our guiding principle based collectively upon these data is that management of NEFA during the transition period is an important factor influencing liver health, the capacity of liver to make glucose, and subsequently production and metabolic disorder incidence in transition cows. The two primary approaches that can be taken are:

1) decrease the supply of NEFA to liver through diet and feeding management (perhaps use of glucogenic supplements)
2) optimize capacity of liver to dispose of NEFA either by burning them for fuel or exporting them as triglycerides in lipoproteins (VLDL)

Good closeup and fresh cow nutritional programs, combined with excellent feeding management to achieve high levels of dry matter intake throughout the transition period, achieves 80 to 90% of the potential of the first strategy and should always be the first area of focus for management. Contrary to popular belief, data supporting that niacin supplementation to the diet decreases concentrations of NEFA are limited; nevertheless, a practical recommendation would be to include niacin (12 g/d) in diets fed to herds struggling with overconditioned cows. Glucogenic supplements such as propylene glycol are effective at decreasing concentrations of NEFA and B-hydroxybutyrate (BHBA; the predominant ketone body found in blood); however, propylene glycol must be drenched or fed such that it is consumed as a bolus in order to be effective in decreasing concentrations of NEFA and BHBA (Christensen et al., 1997), and thus presents both cost and labor challenges. The duration of treatment in most experiments reported in the literature ranges from 10 to 40 days per cow. Recently, two experiments have been conducted (Pickett et al., 2001; Stokes and Goff, 2001) that report beneficial effects of drenching propylene glycol beginning on the day of calving and continuing for one or two subsequent days (Figure 3) -- these short-term treatments are much more acceptable from a cost and labor standpoint and have more potential for commercial application.

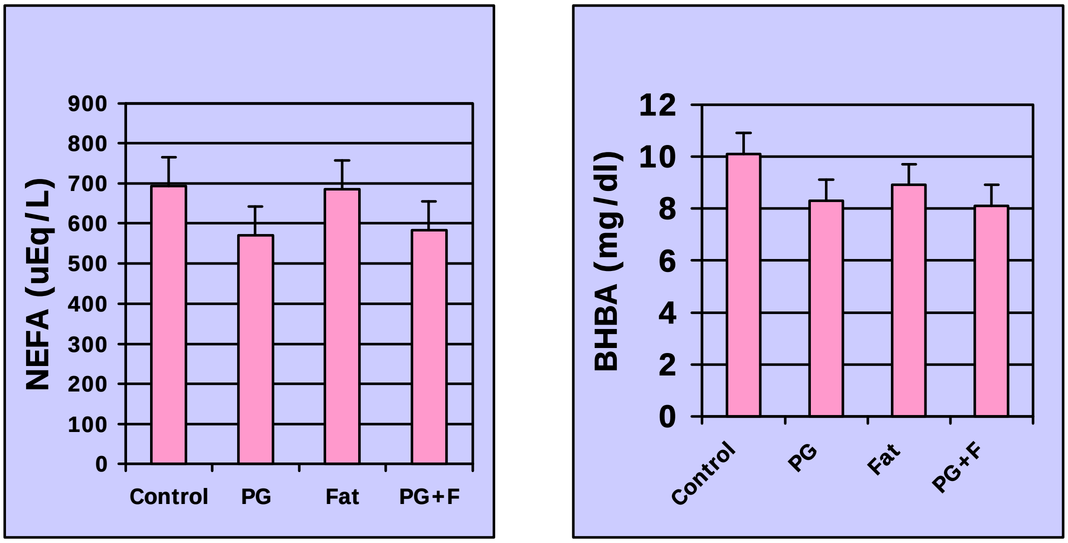

Figure 3. Concentrations of NEFA (left pane) and BHBA (right pane) during d 2 through 7 postcalving for cows drenched with either a control, propylene glycol (500 ml/d; PG), fat (454 g/d), or a combination of propylene glycol and fat for the first 3 d postcalving (Trend for effect of PG; P < .11 for NEFA and P < .09 for BHBA). From Pickett et al. (2001).

Recently, another strategy related to decreasing energy demands on the transition cow has been suggested to potentially decrease reliance on body reserves and thereby reduce the supply of NEFA to the liver. In typical midlactation cows, approximately 50% of the fatty acids secreted as milk fat are taken up by the mammary gland from the bloodstream as preformed fatty acids. The remaining 50% of fatty acids in milk are synthesized de novo in the mammary gland, and account for approximately 50% of the energetic cost of milk synthesis (NRC, 2001). Conjugated linoleic acids (CLA), specifically the *trans*-10, *cis*-12 isomer of CLA, have been discovered to be potent inhibitors of milk fat synthesis (Bauman et al., 2000). Giesy et al. (1999) fed cows 50 g/d of a mixture of CLA isomers (35% *trans*-10, *cis*-12 by weight) in a Ca-salt form from d 13 through 80 postpartum. They reported few effects of CLA supplementation on cow performance during d 14 through 28 postcalving; however, milk yield was increased, and percentage and yield of milk fat were decreased, during d 35 through 80 postpartum. Energy balance was not affected by treatment during either period. Given that supplementation with CLA in their experiment began after concentrations of NEFA have returned to relatively low levels in the blood (Overton and Piepenbrink, 1999), we hypothesized that supplementation of CLA during the entire transition period and early lactation would be more effective in terms of potentially decreasing energy demand during early lactation. Bernal-Santos et al. (2001) fed cows 42.8 g/d of a mixture of CLA isomers (29% *trans*-10, *cis*-12 by weight) in a Ca-salt form from 14 days before expected calving through 140 days of lactation. Results were similar to those of Giesy et al. (1999) in that milk yield and milk fat percentage during the first two weeks postpartum were not affected by CLA supplementation; however, milk fat percentage was decreased by 13% and milk yield tended to be increased (6.6 lb/day) during the entire postpartum period in cows administered the CLA supplement (Table 1; Figure 4; Figure 5). Energy balance and concentrations of NEFA and BHBA in plasma were not affected by treatment. Therefore, contrary to our hypothesis, CLA supplementation does not appear to substantially reduce reliance on body fat stores; however, energy spared from milk fat synthesis apparently was redirected to lactose synthesis and may offer the opportunity to use CLA as a management tool to increase peak milk yield.

Table 1. Least squares means for DMI and yield and composition of milk from cows fed a control or a CLA supplement from 2 wk prepartum through 20 wk postpartum (Bernal-Santos et al., 2001).

	Week 1 through Week 8					Week 1 through Week 20				
	Treatment			P-value		Treatment			P-value	
Item	Control	CLA	SEM	TRT	TRT*WK	Control	CLA	SEM	TRT	TRT*WK
DMI, kg/d	20.5	21.6	0.6	0.23	0.84	23.5	23.9	0.5	0.65	0.11
Milk, kg/d	42.6	45.2	1.2	0.14	0.07	44.1	47.0	0.9	0.12	0.48
Fat, %	3.84	3.46	0.11	0.01	0.62	3.61	3.15	0.08	0.001	0.06
Fat, kg/d	1.60	1.51	0.06	0.31	0.89	1.57	1.45	0.05	0.12	0.58
3.5% FCM, kg/d	44.4	44.1	1.4	0.99	0.88	44.5	43.9	1.3	0.74	0.98
True protein, %	2.87	2.89	0.06	0.79	0.44	2.77	2.74	0.04	0.60	0.28
True protein, kg/d	1.20	1.27	0.04	0.19	0.97	1.21	1.26	0.03	0.27	0.98
Lactose, %	4.69	4.73	0.05	0.58	0.15	4.74	4.74	0.05	1.0	0.05
Lactose, kg/d	2.00	2.14	0.06	0.58	0.15	2.09	2.22	0.06	0.15	0.89
MUN, mg/dl	12.8	12.7	0.4	0.82	0.55	12.2	12.0	0.4	0.70	0.89
SCC (x1,000)	234	274	35	0.70	0.23	384	426	156	0.84	0.49

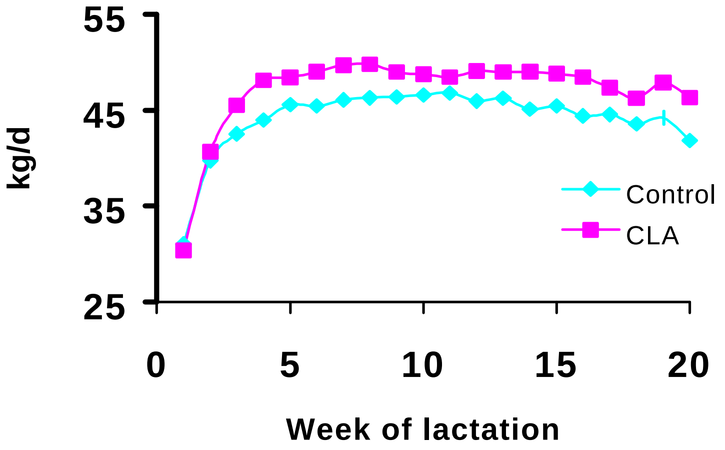

Figure 4. Least squares means for milk yield by week of lactation for cows fed either a control or a CLA supplement. Pooled SEM = 0.9. (Bernal-Santos et al., 2001).

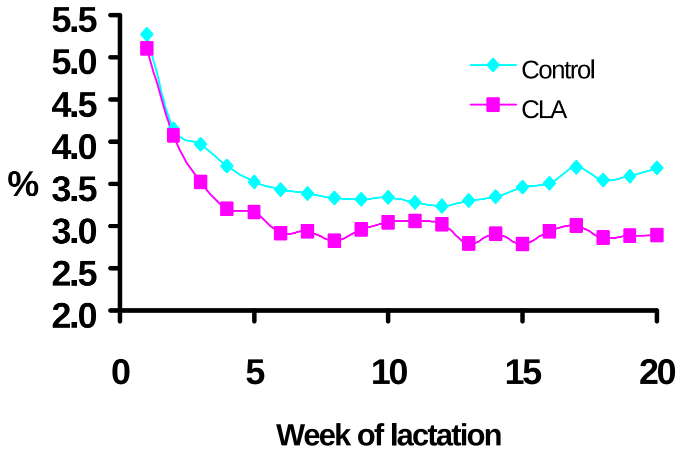

Figure 5. Least squares means for milk fat percentage by week of lactation for cows fed either a control or a CLA supplement. Pooled SEM = 0.1. (Bernal-Santos et al., 2001)

Even when the first strategy is in place on individual dairy farms, we believe that there are opportunities to further improve liver health by employing nutritional strategies to optimize the capacity of liver to dispose of NEFA rather than accumulate them as fat in liver tissue. As mentioned above, the two disposal routes of NEFA from liver involve burning them for fuel and exporting them back into the blood as triglycerides in very low density lipoproteins (VLDL; Figure 2). We reviewed the background data and theory supporting the potential for several candidate nutrients (choline, methionine and lysine) last year, and reported that choline supplementation to diets fed to transition dairy cows resulted in decreased rate of accumulation of fat in liver measured using an in vitro system (Figure 6; Piepenbrink and Overton, 2000). We now know that this decreased rate of accumulation of fat in liver was accompanied by a trend for increased capacity of liver to convert propionate to glucose (Figure 7). We also reported that milk production was sensitive (Table 2) to the supply of methionine as provided by its analog, 2-hydroxy-(4-methylthio)-butanoic acid (HMB); however, the capacity of liver to metabolize NEFA was not affected by HMB supply (Figure 8; Piepenbrink et al., 2001). Further research must be conducted to determine the specific roles of choline, methionine, and lysine in liver fatty acid metabolism and to determine the interactions among supply of these nutrients.

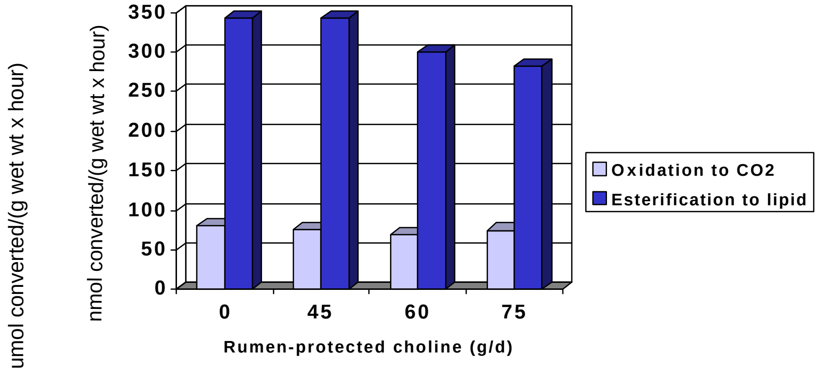

Figure 6. Conversion of [1-^{14}C]palmitate to CO_2 and esterified products by liver slices from cows fed increasing amounts of rumen-protected choline (Piepenbrink and Overton, 2000).

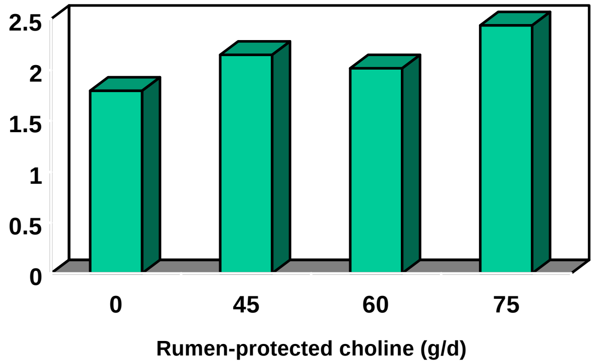

Figure 7. Conversion of [1-^{14}C]propionate to glucose by liver slices from cows fed increasing amounts of rumen-protected choline (Linear, $P < 0.15$; SEM - 0.27; Piepenbrink and Overton, 2000).

Table 2. Least squares means for yield of milk and composition and yield of milk components from cows fed increasing amounts of 2-hydroxy-4-(methylthio)-butanoic acid (HMB) during the transition period and early lactation (Piepenbrink et al., 2001).

	Treatment				Effect, P <		
Item	Control	+ HMB	++ HMB	SEM	TRT Linear	TRT Quad.	TRT x week
Milk, lb/d	92.6	99.2	92.6	2.9	0.99	0.05	0.13
Fat, %	4.20	4.00	4.07	0.13	0.46	0.36	0.80
Fat, lb/d	3.79	3.88	3.70	0.11	0.59	0.32	0.40
3.5% FCM, lb/d	101.4	105.8	100.1	2.6	0.70	0.11	0.28
CP, %	2.80	2.77	2.84	0.06	0.65	0.33	0.26
CP, lb/d	2.56	2.69	2.58	0.09	0.77	0.22	0.69
Lactose, %	4.70	4.69	4.73	0.05	0.62	0.69	0.76
Lactose, lb/d	4.34	4.65	4.39	0.13	0.86	0.05	0.19
Total solids, %	12.46	12.22	12.38	0.19	0.78	0.36	0.94
Total solids, lb/d	11.40	11.99	11.35	0.31	0.94	0.09	0.53

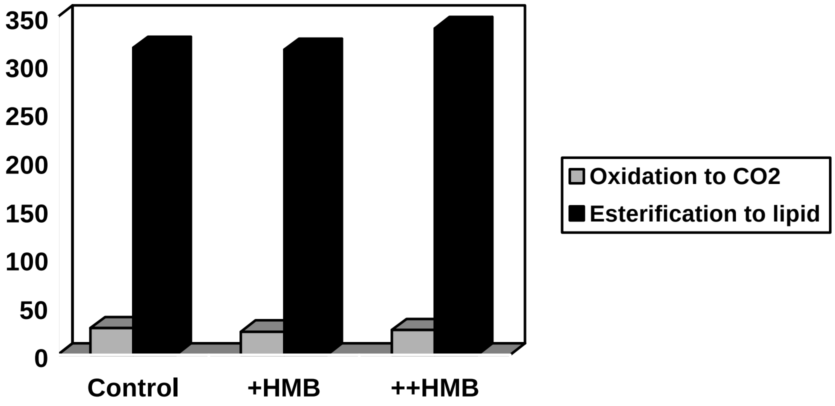

Figure 8. Conversion of [1-^{14}C]palmitate to CO_2 and esterified products by liver slices from cows fed increasing amounts of 2-hydroxy-(4-methylthio)-butanoic acid (HMB; Piepenbrink et al., 2001).

GROUPING STRATEGIES AND DIET FORMULATION FOR CLOSEUP COWS

Modern dry cow nutritional grouping strategies involve a two-group system -- a "far off" group consisting of cows from dry off through approximately 21 d prepartum and a "closeup" group consisting of cows from approximately 21 d prepartum through parturition. We would recommend energy densities of approximately 0.59 to 0.63 Mcal/lb of net energy for lactation (NE_L) for diets fed to cows in the far off group. More detailed recommendations for diets fed to closeup cows, with differentiation on mineral composition based upon anionic versus nonanionic approaches to manage hypocalcemia, are provided in Table 3.

Table 3. General goals for diet formulation for closeup cows

	Standard	Anionic
• NE_L, Mcal/lb	0.72 to 0.74	
• Metabolizable protein, g/d	1100 to 1200	
• NSC, %	34 to 36	
• Dietary Ca, g/d	100	140
• Dietary Ca, %	0.90	1.2
• Dietary P, %	0.3 to 0.4	0.3 to 0.4
• Mg, %	0.4 to 0.42	0.4 to 0.42
• Cl, %	0.3	0.8 to 1.2
• K, %	< 1.3	< 1.3
• Na, %	0.1 to 0.2	
• S, %	0.20	0.3 to 0.4
• Vitamin A (IU/d)	100000	100000
• Vitamin D (IU/d)	30000	30000
• Vitamin E (IU/d)	1800	1800

More uncertain is the length of time that cows should be fed the closeup diet. Two experiments have been published recently that provide us with some insight on this topic. Robinson et al. (2001) fed cows and first-calf heifers either a control closeup diet or a closeup diet supplemented with additional energy and protein on commercial dairy farms in the West and determined that there was a significant increase in milk yield over a full lactation when heifers and cows were fed these diets for 15 d compared with 5 d (Figure 9). Additional supplementation of energy and protein to the diet yielded more milk during the full lactation only when it was fed for 15 d prepartum. This experiment, however, did not explore feeding the closeup diet for longer than the 21 d currently recommended. Mashek and Beede (2001) fed cows on two commercial dairy farms the closeup diet for an average of either 18 d or 37 d prepartum. There was a slight improvement in energy status of cows fed the closeup diet for 37 d prepartum; however, differences in milk production during early lactation were not significant. Health effects were farm-specific -- one farm had an increased incidence of retained placenta when fed the closeup diet for an average of 37 d prepartum.

We recently completed an experiment on two commercial dairy farms in New York involving nearly 400 cows in which we fed cows either a two-group dry cow program or the closeup diet for the entire dry period (Contreras, Ryan, and Overton, unpublished data). Differences in productive performance during the first five monthly test days were not significant among treatments. In looking at interactions of body condition score at dry off with performance during the subsequent lactation, we found that cows with initial body condition score less than 3.0 (mean = 2.8) tended to produce more milk (43.0 kg/d versus 41.3 kg/d) across the first five monthly test days than did cows with body condition score of 3.25 or greater (mean = 3.4). Furthermore, a trend existed for an interaction of body condition score at dry off such that thinner cows fed a two-group dry cow program produced the most milk (44.1 kg/d) during the first five monthly test days, cows fed the closeup diet for the entire dry period were intermediate (42.0 kg/d for both body condition score groups), and heavier cows fed a two-group dry cow program produced the least milk (40.6 kg/d) during the first five monthly test days. The implications of these data are that replenishment of body condition during late lactation to a body condition score of 3.25 or 3.50 as commonly recommended may not be as important for productive performance if cows are fed "modern" transition cow feeding programs. Secondly, these data also imply that perhaps heavier cows will benefit from spending the entire dry period in the closeup group. Certainly, more research investigating the interactions of body condition score and nutritional strategies for transition cows is merited.

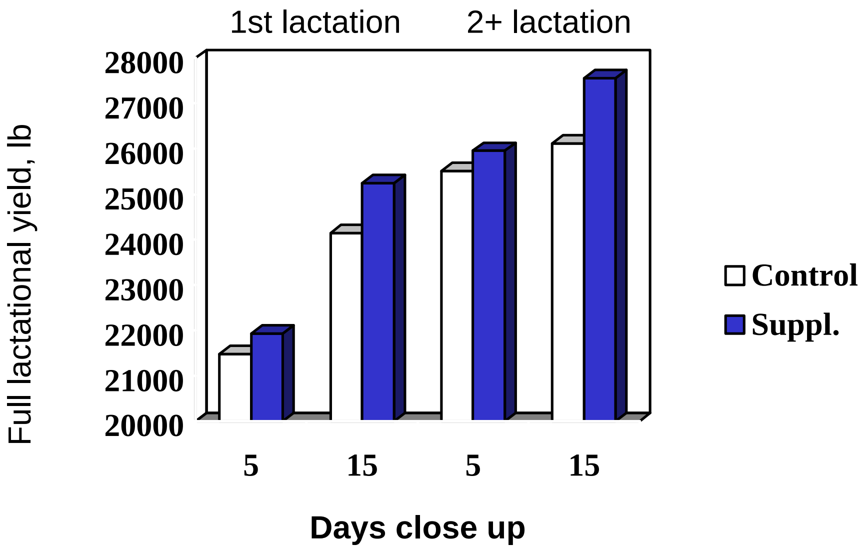

Figure 9. Full lactational milk yields of cows in first and second or greater lactation as affected by feeding either a control or supplemented diet for either five or fifteen days closeup (Robinson et al., 2001).

CURRENT RESEARCH, AND IMPLICATIONS FOR THE DAIRY INDUSTRY

Currently, our laboratory is engaged in experiments to elucidate the specific roles of individual nutrients in liver metabolism of transition cows and to determine the interactions of metabolism and health that likely provide the biological basis for the myriad of factors that we include in the category of "management" on commercial dairy farms. Collectively, this research will provide much of the basis for managing metabolism of transition dairy cows in transition cow nutrition and management programs in the future.

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