NUTRITIONAL MANAGEMENT OF DAIRY COWS DURING THE TRANSITION PERIOD

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Introduction

The transition period for dairy cows, which refers to the time from 3 weeks before through 3 weeks after calving, is now recognized as the most critical phase of the lactation cycle. Nutrition and management during this period essentially determine the profitability of the cow for the remainder of the lactation. A problem-filled transition gets cows off to a poor start to lactation. Signs of an inadequate transition program include cows that are slow to come onto feed after calving, an excessive incidence of metabolic disorders, cyclic feed intakes, and excessive loss of body condition after calving (Drackley, 1996).

Most metabolic and infectious diseases occur during the transition from dry period to early lactation, leading to increased costs for veterinary treatment and to lost production potential. Every 1 pound of milk lost from the cow's potential peak production represents a loss of 200 lbs of milk for the lactation. Problems during the transition period often result in the loss of 10 to 20 lbs of peak milk, which translates into economic losses of $300 to $600 for that lactation. Health problems during the transition may decrease reproductive performance, resulting in additional economic losses.

Furthermore, to maximize productivity and ensure successful reproduction, rations fed during this time need to be nutrient dense and often contain more expensive ingredients. Improper formulation of diets and poor feeding management can end up negating beneficial effects of these more costly rations (Drackley, 1996). Therefore, a poor nutritional program during the transition increases feed costs per unit of milk produced and decreases income through lost milk production, decreased reproductive efficiency, and increased incidences of metabolic disorders.

To obtain maximum profits, the dairy producer must work together with the nutritionist and veterinarian to design practical strategies to help cows make smooth transitions, so that cows produce to their potential during early lactation. Most of the "metabolic upheaval" that cows will face during the transition from pregnancy during the late dry period to lactation has occurred by the first day after calving (Grummer, 1995). Consequently, management and nutrition during the transition period assumes tremendous importance. Maximizing postpartum dry matter intake (DMI) should be the central management focus during this time period.

Metabolic Changes During the Transition

To understand and implement nutritional management recommendations for the transition period, it is helpful to understand the metabolic events that occur during this time (Drackley, 1997; Goff and Horst, 1997). As parturition nears, concentrations of progesterone in blood decrease and those of estrogen remain high or actually increase (Grummer, 1995). The high circulating estrogen is believed to be one major factor that contributes to decreased DMI around calving (Grummer, 1993). During the last weeks of pregnancy, nutrient demands by the fetus and placenta are the largest of any point during gestation (Bell, 1995), yet DMI may be decreased by

10 to 30% compared with intake during the early dry period.

After calving, the initiation of milk synthesis and rapidly increasing milk production greatly increases demand for glucose for milk lactose synthesis, at a time when feed intake has not reached its maximum. Because much of the dietary carbohydrate is fermented in the rumen, little glucose is absorbed directly from the digestive tract. Consequently, dairy cows rely almost exclusively on gluconeogenesis (synthesis of glucose) from propionate in the liver to meet their glucose requirements. Limited feed intake during the early postpartal period means that supply of propionate for glucose synthesis also is limited. Amino acids from the diet or from breakdown of skeletal muscle as well as glycerol from mobilized body fat contribute some carbon for glucose synthesis. Supplying adequate glucose for milk synthesis is considered to be the single greatest metabolic challenge to cows during early lactation (Drackley, 1993).

Total energy intake by cows after calving usually is less than energy requirements. Negative energy balance results in a high ratio of growth hormone to insulin in blood of cows, which promotes mobilization of long-chain fatty acids from adipose tissue. During late gestation and around the time of parturition, adipose tissue becomes very susceptible to actions of lipolytic hormones, such as the catecholamines epinephrine and norepinephrine (McNamara, 1988). Fatty acids released from adipose tissue circulate as nonesterified fatty acids (NEFA), which are a major source of energy to the cow during this period. Indeed, during the first month of lactation, the energy in stored lipids that are mobilized by the cow may account for about 33% of the milk produced (Moe, 1965).

The liver of cows extracts an essentially constant percentage of the NEFA in blood that flows through it. Once taken up by the liver, NEFA can be 1) completely oxidized to carbon dioxide to provide energy for the liver, 2) partially oxidized to produce the ketone bodies (β-hydroxybutyrate [BHBA] and acetoacetate) that are released into the blood and serve as fuels or substrates for other tissues, or 3) esterified to form triglycerides. Factors that regulate the flow of NEFA among these three paths in liver are understood poorly in ruminants (Grummer, 1993). Carbohydrate insufficiency in the liver during the early postpartal period leads to incomplete oxidation of NEFA and increased production of ketone bodies, which can result in ketosis. Increased ketone bodies in blood have been associated with decreased feed intake (Baird, 1982). Factors that decrease oxidation of NEFA generally increase esterification (Grummer, 1993).

In many nonruminant species, triglycerides made in the liver can be packaged into lipoprotein particles and exported out of the liver into blood, where the triglyceride fatty acids can be taken up by the mammary gland, skeletal muscle, and adipose tissue. However, in ruminants, the ability to export triglycerides from the liver is very limited (Kleppe et al., 1988; Pullen et al., 1989). This results in an increased likelihood that cows will accumulate triglyceride in the liver, leading to the condition of fatty liver. Cows fed typical diets during the dry period and transition period have an increased concentration of triglyceride in the liver 1 day after calving (Bertics et al., 1991; Grum et al, 1996b; Studer et al., 1993). This results from greatly increased concentrations of NEFA around calving (Vazquez-Añon et al., 1994), increased uptake of NEFA by the liver, and increased activity of the enzymatic pathway that converts NEFA to triglyceride in the liver (Grum et al., 1996b).

Maintaining optimal liver function is central to the ability of cows to make a smooth transition into heavy milk production. As the degree of fatty infiltration increases, normal functions of the liver are affected adversely (West, 1990). In severe fatty liver, normal functions of the liver are severely depressed, which results in the condition of "fatty liver syndrome" or "clinical fatty

liver" (Morrow, 1976). Increased triglyceride in liver appears to precede ketosis in most cases (Veenhuizen et al., 1991; Grummer, 1993), and cows with an enhanced ratio of triglyceride to glycogen are at increased risk for development of ketosis (Drackley et al., 1992; Hippen et al., 1997).

Feed intake and carbohydrate status of the cow are important in determining the extent of body fat mobilization, fatty liver, and ketone body production in the liver. Cows that are in severe negative energy balance have decreased concentrations of insulin, which allows rapid mobilization of NEFA from adipose tissue and also allows greater conversion of NEFA to triglycerides and ketone bodies in the liver. In addition, the supply of propionate from rumen fermentation is an important regulator of metabolism in the liver. In addition to providing glucose for milk lactose synthesis, metabolism of propionate to glucose by the liver decreases the oxidative breakdown of NEFA and the production of ketone bodies by the liver (Emery et al., 1992). Consequently, supply of propionate as determined by feed intake and dietary composition is critical to metabolism during the transition period.

Importance of Peripartum Feed Intake

As discussed above, nutrient intake is critical to minimize the extent and duration of negative energy balance after calving. Bell (1995) presented data demonstrating that nearly all of the energy and protein consumed by cows at 4 days after calving were needed by the mammary gland for milk synthesis, leaving little for maintenance functions (Figure 1). Maximizing nutrient intake lessens the dependence on body stores of energy and amino acids. Greater intake increases the supply of amino acids for milk protein synthesis and probably for glucose synthesis, and provides more acetate and propionate from ruminal fermentation for use as energy and glucose sources, respectively. Greater intake also increases release of insulin, which modulates or suppresses mobilization of body fat, and increases propionate supply, which decreases ketone body synthesis.

Extreme negative energy balance around the time of parturition poses a great risk for development of ketosis. Withholding feed to lactating dairy cows at 1 week postpartum results in ketosis, yet starvation during later lactation or in a nonlactating cow does not (Baird, 1982). We have recently demonstrated that limiting feed intake to 50% of the previous day's intake at day 5 postpartum resulted in clinical ketosis in 8 out of 10 cows (Bahaa et al., 1997). In contrast, restricting feed intake by 20% starting at day 14 postpartum did not reliably produce ketosis (Drackley et al., 1991). Restricting feed intake by as much as 50% during week 4 to 5 of lactation also did not result in ketosis (de Boer et al., 1985), indicating the importance of feed intake during the immediate postpartum period.

Other evidence also implicates the importance of feed intake in the development of metabolic disorders. Zamet et al. (1979) found that DMI decreased 30% between days 7 and 1 prepartum. Cows that had any health disorder after calving had 18% lower DMI before calving and 20% lower DMI after calving than apparently healthy cows. Bertics et al. (1991) force-fed a group of cows through rumen cannulas in an attempt to prevent the decreased DMI before calving. Feed intake of control cows declined 28% during the last 17 days prepartum. Liver triglyceride content 1 day after calving was 227% and 75% greater than at 17 days before calving for controls and force-fed cows, respectively.

Lean et al. (1994) examined production and metabolic variables in three groups of cows

within a large California dairy herd. Cows were grouped as nonketotic, ketonemic, and clinically ketotic. Energy balance and DMI were similar between the nonketotic and ketonemic cows, but were markedly lower for clinically ketotic cows. In that study, the decreased DMI and energy balance preceded the diagnosis of clinical ketosis by about 6 days. Of all the variables measured, decreased DMI and energy balance represented the most pronounced differences between ketotic cows and normal or ketonemic cows.

For Holstein cows, DMI should be at least 34 to 38 lb (15 to 17 kg) per day by the end of the first week after calving (Table 1). Lower DMI suggest that the transition program can be improved. Grummer (1995) found that DMI of individual cows on the day before calving was correlated r = 0.54) with DMI of the same cows 21 days after calving. This relationship suggests that cows that do not eat well before calving will not eat well after calving, and emphasizes the importance of nutrition and feeding management during the dry period and transition period. A number of nutritional and management factors affect DMI during the transition period.

Factors Affecting Feed Intake During the Transition

Body Condition

The optimal body condition score for cows entering the dry period and at calving remains controversial. It is clear, however, that overfeeding during the dry period so that cows are overconditioned (>4.0 on a 5-point scale) are at greater risk for development of metabolic problems (Fronk et al., 1980; Gardner, 1969; Morrow, 1976). Overconditioned cows have poorer DMI after calving (Bines and Morant, 1983; Fronk et al., 1980), have greater stores of body fat that can be mobilized, and readily develop insulin resistance (Holtenius, 1993), which allows greater mobilization of fat from adipose tissue and enhanced fat deposition in the liver. Obesity leads to increased susceptibility of the complex of metabolic disorders and infectious diseases known as the "fat cow syndrome" (Morrow, 1976) and should be avoided.

Ferguson and Otto (1989) concluded that cows whose body condition falls below 2.5 have decreased milk production and reproductive problems. They suggested that cows scoring 3 at calving would produce amounts of milk similar to cows scoring 4 at calving, but only if postpartum rations are of high quality and intake is truly ad libitum. These conditions often are not met in the field; consequently, milk production will drop if body energy reserves are insufficient. For most managers, a body condition score of between 3.5 and 3.75 appears to be a suitable compromise between adequate and excessive body condition (Shaver, 1993). In a well-managed high-producing herd, Waltner et al. (1993) found that fat-corrected milk yield in the first 90 days of lactation was maximized when the body condition score was 3.5 at calving.

Feeding Management

Easy access to fresh and high-quality water is critically important for maximal DMI. Water is the single most important nutrient but the most often neglected. Watering devices must be kept clean. Transition cows should not have to walk long distances to obtain water.

Feed bunk management probably is as important in maximizing feed intake as diet formulation. Producers must be aware that unless about 10% or more feed is left in the bunk every day, cows will not be achieving maximal DMI. Obviously, producers are reluctant to "waste" feed by feeding for such a high rate of refusals, even if the refused feed can be recycled to other

groups of cattle. However, during the transition period, feeding to ensure 5 to 10% refusals will be worth the extra labor and cost. Feed bunks should never be empty of high-quality feed for cows during the first few weeks after calving!

All cows, including fresh cows, timid cows, and first-calf heifers, must have ample bunk space to eat whenever they want. In larger herds, grouping strategies are important to ensure that some cows are not deprived of feed due to social stresses from overaggressive herdmates (Davidson et al., 1997). Feed should be kept fresh, with bunks cleaned regularly to prevent buildup of spoiled or moldy feed. This is especially important in hot climates where feed quickly goes out of condition. Intake often can be increased by covering concrete mangers or bunks with plastic liners or ceramic tile.

Feeds fed to far-off dry cows are often vastly different from those fed in the fresh cow diet. Gradual adaptation to the ingredients that will be fed after calving is important during the transition period. Exposing cows prepartum to small quantities of ingredients such as tallow or other fats and animal protein by-products may help to improve acceptance and DMI after calving, but care must be exercised that prepartum intake is not depressed by these ingredients (Drackley, 1993). Introductions of such feedstuffs need to be very gradual during the transition period.

A fascinating example of the importance of feeding management is found in the data from a preliminary study by Bertoni et al. (1994). Two groups of 3 cows each were fed the same diet consisting of corn silage, alfalfa-grass hay, and concentrate. Forages were offered at 0700 and 1500 hours to both groups. Concentrates were allocated according to milk production in 8 feedings daily. For group 1, concentrate feedings were spaced so that the interval between the last feeding at night and the first feeding in the morning was 8.5 hours. For group 2, the longest interval without concentrate was 5 hours. Results for the first 4 weeks after calving are shown in Table 2. This seemingly subtle difference in how cows were fed resulted in marked differences in metabolic responses between the groups. Cows that were without feed for the longer time had higher plasma concentrations of NEFA, BHBA, and urea, but a lower concentration of glucose. Milk production was similar, but feed intake was 4.4 lb lower for the group without feed the longest. The results suggest that a longer interval without feed caused greater mobilization of body tissue to support the same amount of milk production; these metabolic changes resulted in lower DMI, which in turn may have further increased body mobilization.

Although the number of cows used in this study was very small, these data illustrate the potential importance of ensuring access to feed throughout the day to maximize DMI and prevent metabolic disorders. Christensen et al. (1997) have made similar conclusions based on the powerful suppressive effect of feed intake on plasma NEFA during feed restriction. Their data suggest that ad libitum feeding of a TMR, or at least feeding several times daily, would be advantageous in pre-fresh and just-fresh cows for prevention of fatty liver and metabolic disorders. Dyk et al. (1995) have shown a clear association between increased body fat mobilization prepartum, as evidenced by elevated NEFA concentrations, and the incidence of metabolic disorders.

Providing feed as a TMR may be especially advantageous for transition cows. Maintaining proper rumen function and pH are critical to avoid off-feed situations from ruminal acidosis. Use of a TMR avoids sorting and slug-feeding of concentrates, which may lead to bouts of acidosis and decreased intake. A TMR also maximizes the likelihood that cows will consume all required nutrients as formulated.

Producers who cannot incorporate a separate fresh cow group but who feed a separate close-up ration can place fresh cows on the high-group TMR immediately after calving, but may wish to feed 4 to 6 lbs of high-quality long hay along with the TMR for the first 2 to 3 weeks. This ensures adequate effective fiber intake and decreases the energy density slightly, which may help cows stay on feed and avoid problems with acidosis, displaced abomasum, and other metabolic disorders.

Formulation of Diets for Transition and Fresh Cows

Recognition of the importance of the transition period on health and lactation performance has increased dramatically in the last few years. Use of a separate transition diet, especially when fed as a TMR, should help cows come onto feed faster and more smoothly after calving, with a lower incidence of postpartum health disorders (Shaver, 1993). Curtis et al. (1985) found that increased intakes of energy and protein during the last 3 weeks before calving were associated with decreased risk of uncomplicated ketosis.

Transition diets need to be formulated to supply adequate nutrients and promote high DMI. Grummer (1995) pointed out the relative lack of research specifically designed to optimize dietary formulation during the transition period, and summarized the available data on effects of prepartum nutrition on metabolic disorders and lactation performance. Excellent practical recommendations for transition strategies using TMR were presented by Shaver (1993).

As mentioned earlier, DMI of cows declines by 10 to 30% during the last 7 to 14 days before calving (Zamet et al., 1979; Bertics et al., 1991). At the same time, nutrient needs for the near-term fetal calf and for the initiation of milk synthesis are at their greatest (Bell, 1995). Optimally, then, producers should provide a separate transition diet that contains increased nutrient densities to compensate for lower DMI. This ration generally should be intermediate in nutrient density to the diet for far-off dry cows and the diet to be fed after calving. The typical decrease in DMI before calving results in the need to increase contents of crude protein and NE_L by about 2 percentage units and 0.10 Mcal/lb of DM, respectively (Table 3). As pointed out by Shaver (1993), the NRC recognized this situation in the latest publication on Nutrient Requirements of Dairy Cattle (NRC, 1989), but the concept has not been widely implemented by producers because of practical difficulties.

Carbohydrates. Although data for effects of prepartum carbohydrate nutrition on transition performance are inconclusive (Grummer, 1995), the balance of structural carbohydrates (fiber) and nonstructural carbohydrates in diets fed before and after calving is probably the most important dietary factor for maximizing feed intake. Examination of the carbohydrate fractions of the transition ration and fresh-cow ration should be the starting point for trouble-shooting transition problems. Unfortunately, the proper balance of these two carbohydrate fractions is not well defined. Adequate fiber of sufficient particle size is needed to maintain rumen function, prevent acidosis and displaced abomasum, and achieve high DMI. On the other hand, excessive NDF content may limit intake. Sufficient nonfiber carbohydrates (sugars and starch provided by grains) must be present to provide adequate energy in the form of propionic acid for glucose synthesis and to suppress synthesis of ketone bodies. Some evidence also links increased grain feeding to improved intake around calving (Grummer, 1995).

Another benefit of addition of grains to the prepartum diet is to adapt the ruminal tissues and the rumen microbial population to the type of diet that will be fed after calving (Goff and Horst,

1997). Grain feeding increases length of the rumen papillae, which are the structures that absorb the volatile fatty acids produced from ruminal fermentation. Research has shown that rumen papillae elongate in the presence of increased concentrations of the volatile fatty acids (Dirksen et al., 1985), thereby increasing the absorptive surface in the rumen. This may be important for preventing acidosis after calving. Care must be taken, however, to avoid excessive amounts of non-fiber carbohydrates, which could cause acidosis and off-feed problems that in turn will increase the risk of ketosis and other problems. Relative effects of cereal grains high in starch versus highly digestible fibrous concentrates such as soy hulls or beet pulp have not been researched.

General recommendations are to ensure that content of neutral detergent fiber (NDF) in the total ration is 30 to 32% of dry matter, with at least 3/4 of this supplied from forages. Forage quality during the transition is critical to achieving high DMI. The best forages on the farm should be reserved for cows during the transition period, both in the pre-fresh and fresh-cow rations. Non-fiber carbohydrates should be in the range of 35 to 40% of dry matter. Particular care must be taken by producers who component-feed cows rather than using a TMR. Concentrates should be given in several meals per day, after forages, to avoid slug-feeding and the resultant acidosis problems.

The proper particle size of chopped forages has not been well-defined through research. Shaver (1993) recommended that at least 20% (by weight) of the forage particles should be 1.5 to 2 inches long. Use of on-farm particle sizing devices, such as the Penn State Separator, is becoming more prevalent, but again, guidelines for transition cows have not been established. Illinois recommendations (Hutjens, 1997) for TMR are that more than 10% of the particles (by weight) should remain on the top screen and 30 to 50% should remain on the middle screen, resulting in less than 50% in the bottom pan. For transition cows, the amounts in the top and middle screen fractions may need to be 10 to 20% greater to ensure prevention of acidosis and off-feed problems. Feeding 3 to 5 lb of high-quality long hay with the TMR after calving may help to ensure proper rumen function and avoid acidosis problems.

Protein. Some evidence links increased protein during the dry period to improved DMI (Grummer, 1995). The NRC guidelines (NRC, 1989) specify a crude protein content of 12% for dry cows. As demonstrated above, intake depression before calving dictates an increase to about 14% protein during the transition. Van Saun (1991) recommended a greater dietary content of protein, with attention given to degradable and undegradable fractions. Increasing dietary crude protein content from 12 to 13.5% by addition of undegradable protein from blood meal improved lactational performance of first-calf heifers (Van Saun et al., 1993) and decreased incidence of ketosis in multiparous cows (Van Saun and Sniffen, 1995). However, those experiments did not allow differentiation of the effects of increased protein in general versus any effect of undegradable protein.

VandeHaar et al. (1995) demonstrated that feeding a diet with nutrient concentrations increased to compensate for decreased prepartum DMI improved nutritional status at calving, but supplementing undegradable protein to that diet had no additional benefit. Feeding a diet containing 15% crude protein during the dry period, with the supplemental protein from soybean meal, resulted in a 69% incidence of metabolic disorders compared with only 7% for cows fed an 8% protein diet (Julien et al., 1977). However, cows fed the high-protein diet were overconditioned, with 30% classified as having the fat-cow syndrome, and the diet was high in soluble and degradable protein fractions.

For fresh cows, the NRC (1989) recommends that dietary protein should be 19%, compared with 18% for the period of peak milk production. The higher protein content was justified on the basis of providing adequate absorbable amino acids when feed intake is limited after calving. Controlled research data on effects of pre- and postpartum protein contents and degradabilities for transition cows are needed desperately.

Fat. Supplemental fat would seem to have merit in minimizing the negative energy balance around and after calving, but increasing evidence indicates that cows may not respond as expected during the transition period. Chilliard (1993) summarized research data on effects of dietary fat during early lactation. Fat supplementation during early lactation decreased DMI by an average of 0.66 lb (0.3 kg) but the response was variable among studies. Furthermore, it now appears that supplemental fat is ineffective at suppressing body fat mobilization in early lactation (Chilliard, 1993). Fat supplementation does not seem to increase milk yield until after the first few weeks of lactation (Grummer, 1995). Consequently, high amounts of supplemental fat are not recommended in the fresh cow ration. If a separate fresh cow group is possible, this recommendation can be implemented, but this is difficult in the absence of such a group.

Large amounts of fat can decrease DMI during early lactation (Jerred et al., 1990). Decreased DMI and replacement of nonfiber carbohydrates by fat could make high rates of fat supplementation after calving a risk factor for ketosis. Our general experience from several experiments at the University of Illinois has been that cows do not increase DMI as rapidly when fed fat-supplemented diets from calving. Limited evidence indicates that increased protein content, particularly from high rumen-undegradable protein sources, may counteract at least some of effects of fat on intake during the early postpartum period (Palmquist and Weiss, 1994).

Our research group has been interested in the potential use of supplemental fat during the dry period to restore body condition to thin cows and as a possible modifier of metabolism. Although most dietary fat bypasses the liver, mechanisms exist for some of the dietary fat to be taken up by the liver, and total utilization of NEFA by liver tissue was increased in cows fed supplemental fat (Grum et al., 1996a). Grum et al. (1996b) attempted to add body condition to cows that dried off with body condition $\leq$3.5 on a 5-point scale. During the dry period, cows (10 per group) were fed one of three diets (Table 4) for ad libitum intake. The control diet contained 70% chopped grass hay and 30% concentrate and had a calculated net energy of lactation (NE_L) of 0.58 megacalories (Mcal) per pound (1.27 Mcal/kg). The two high-energy diets contained 0.65 Mcal/lb (1.44 Mcal/kg), with the increased energy supplied either from fat or additional concentrate. All cows were fed the same transition diet for the last 7 days before expected calving, consisting of 2/3 grass hay and 1/3 of the lactation TMR. Because of poor forage quality, we were not successful in increasing body condition during the dry period; cows fed fat during the dry period actually decreased body condition because DMI was depressed (Grum et al., 1996b).

Surprisingly, however, accumulation of triglyceride in the liver 1 day after calving was essentially abolished in cows fed the fat-supplemented diet during the dry period, averaging 7.3, 1.4, and 5.9% of wet weight for cows fed control, fat-supplemented, and high-grain diets, respectively. This decreased fat was accompanied by a smaller increase in plasma NEFA concentration around calving, increased peroxisomal β-oxidation (an alternate pathway for disposal of NEFA) in liver, and decreased capacity to esterify NEFA. Because nutrient intakes were decreased in the fat-supplemented group, we cannot say with certainty that the fat supplementation per se was the cause of the altered lipid metabolism. However, Holtenius et al. (1996) reported similar effects on metabolism in cows fed a high-fat diet before calving. Follow-up

studies are underway in our research group (Douglas et al., 1997, unpublished data) and are needed to determine whether such a practice might be beneficial.

Minerals. Increased knowledge in recent years of the effects of subclinical hypocalcemia and its prevention through manipulation of dietary cation-anion difference may have important implications for transition success (Goff and Horst, 1997). Hypocalcemic cows have decreased motility in the digestive tract, which decreases DMI (Goff and Horst, 1997; Hove, 1986). Controlling cation-anion difference of the transition diet should not only decrease incidence of milk fever, but lead to decreased incidence of other metabolic disorders (Horst et al., 1997). Practical recommendations for calculation of cation-anion balance and implementation of anionic salt programs have been presented by several authors (Beede, 1992; Goff and Horst, 1997; Horst et al., 1997; Oetzel, 1991). Managing cation-anion difference with anionic salts can be a "double-edged sword": DMI and transition success may be increased but anionic salts are unpalatable and may decrease DMI if fed in excessive amounts or not managed properly.

Popular press reports have occasionally implicated deficiencies of trace minerals such as copper and zinc in the etiology of metabolic disorders, although there are no data from controlled studies demonstrating such a link. The trace elements play important roles in immune function and regulation of metabolism, and deficiencies may decrease DMI. Nutritionists should ensure that all trace nutrients are provided in adequate amounts and in highly bioavailable forms in diets for transition and fresh cows.

Feed Additives

Buffers and Alkalinizers. Buffers or alkalinizing compounds may be useful in stabilizing the rumen environment during the transition. Direct evidence for positive effects during the transition is limited. Furthermore, benefits may not be expected when diets contain relatively large amounts of high quality alfalfa (Davidson et al., 1997). Inclusion of buffering compounds in the prepartum diet is not recommended, because of the effects of the sodium or potassium cations in aggravating the dietary cation-anion difference (Horst et al., 1997).

Propylene Glycol. Propylene glycol has been widely used as a preventative and treatment for ketosis. If propylene glycol itself does not decrease feed intake, its benefits in modulating body fat mobilization (Studer et al. 1993) might be useful to help cows adapt to lactation. Dietary administration (4 or 8 oz per day) on grain or silage decreased milk ketone concentrations and increased milk production by about 1 lb per day (Emery et al., 1964). Feeding propylene glycol as 3, 6, or 9% of the concentrate during the first 8 week of lactation decreased milk ketone concentrations and had no effect on DMI (Fisher et al., 1973). Daily oral drenches of 1,000 ml (about 34 oz) of propylene glycol beginning 7 days before expected calving until calving decreased prepartum plasma concentrations of BHBA and NEFA, increased concentrations of glucose and insulin, and decreased triglyceride accumulation in the liver 1 day after calving (Studer et al., 1993). The DMI also tended to be greater early postpartum for cows dosed with propylene glycol prepartum (Studer et al., 1993). This dosage, however, is much higher than usually recommended. A once-daily dose of 296 ml (about 10 oz) was nearly as effective as a dose of 887 ml (about 30 oz) in suppressing concentrations of NEFA and BHBA in plasma of feed-restricted heifers (Grummer et al., 1994).

Because daily drenching is laborious, it would be more convenient to feed propylene glycol. Christensen et al. (1997) compared administration of about 325 ml of propylene glycol per day by

once-daily drenching, feeding once daily mixed with concentrate fed separately from the forage, or mixed with the TMR. Feeding once daily in concentrate led to more pronounced and prolonged increases in insulin and decreases in BHBA than feeding in the TMR. From the available data, it appears that supplementation of 8 to 16 oz of propylene glycol daily in a small amount of concentrate may be an effective alternative to daily drenching for decreasing incidence of metabolic problems. The main disadvantage of propylene glycol is its high cost.

Recently, dry calcium propionate supplements have become available. Although few published data are available on their efficacy in promoting smoother transitions, the cost and inclusion rates may be more favorable than oral paste preparations or propylene glycol.

Protected Amino Acids. Durand et al. (1992) showed that intravenous infusion of methionine and lysine increased triglyceride export from the liver of dairy cows, which might help avoid problems with low DMI caused by fatty livers. Some evidence indicates that protected methionine and lysine may be beneficial to DMI and production during the transition and early lactation period (Davidson et al., 1997) although results have not been consistent (Overton et al., 1996). Recent research at the University of Wisconsin (L. E. Armentano, unpublished data) has suggested that protected amino acids may be useful during the transition period.

Niacin. Feeding niacin at 6 grams per head per day for the last 2 weeks before calving through the first 8 to 12 weeks postpartum may be helpful in preventing ketosis, although evidence for its benefit is conflicting (Drackley, 1992; Fronk et al., 1980; Skaar et al., 1988). Niacin has had no consistent effect on feed intake in transition cows. Niacin may exert any beneficial effects through actions on glucose metabolism, rather than on suppression of lipid mobilization as commonly assumed (Drackley, 1992). Additional metabolic measurements of niacin status and its effects on cellular energy metabolism likely would contribute to the knowledge base for objective decisions on the usefulness of niacin during the transition period.

Yeast Culture. Yeast cultures have been suggested to provide stimulatory factors for growth of certain rumen microbial species, which might translate into improved digestive efficiency, increased feed intake, and increased production. Feeding yeast cultures prepartum increased DMI in two studies (Wohlt et al., 1995; McCoy et al. 1997) but not in another (Robinson, 1997). Few data on metabolic effects during the transition are available.

Chromium. A Canadian study (Yang et al., 1996) indicated that chelated chromium increased feed intake after calving in first-lactation heifers, but not in multiparous cows. Data in various species indicating benefits of chromium on metabolism and immune function are intriguing but as of yet are inconclusive for transition dairy cows.

Feed flavors. Recent evidence has suggested that addition of sucrose as a flavoring agent might enhance DMI during the first 2 weeks after calving (Nombakela et al., 1995). Other flavoring agents (anise, monosodium glutamate, dehydrated alfalfa meal flavor, and molasses flavor) did not affect DMI (Nombakela et al., 1994).

Maximizing Cow Comfort and Minimizing Stress

Cow comfort is especially important during the transition period (Shaver, 1993). Some evidence indicates that cows that undergo abrupt social and environmental changes around the calving are more prone to metabolic disorders (Shaver, 1993). Cows will be uncomfortable as parturition approaches, in addition to a period of time after parturition that may vary depending on

the ease of the birth. Producers should strive to keep these cows clean, dry, and on good footing. Protection is needed from wind in cold climates and from the sun in hot climates. Cows in maternity pens should be fed exactly the same ration that they were being fed before being moved to the pen. Handling fresh cows separately or as a separate group minimizes competition between fresh cows and more aggressive herdmates. Social and environmental stresses during this time will lead to catecholamine-induced increases in plasma NEFA concentration, which increases the likelihood of low intakes and development of metabolic disorders (Gerloff, 1988).

Summary

Excellent nutrition and feeding management during the transition period will help to maximize DMI, which in turn will go far toward ensuring a successful, trouble-free transition. Several management practices will help to increase feed intake around the time of calving. These practices include proper body condition, feeding management, excellent quality forages, proper contents of fiber and non-fiber carbohydrates, attention to the cation-anion balance of the diet, and maximizing cow comfort. Some feed additives may be helpful, but should be viewed as a means to "fine-tune" the nutritional program and not as a "magic bullet" to solve problems attributable to deficiencies in the basics of nutrition and management of transition cows.

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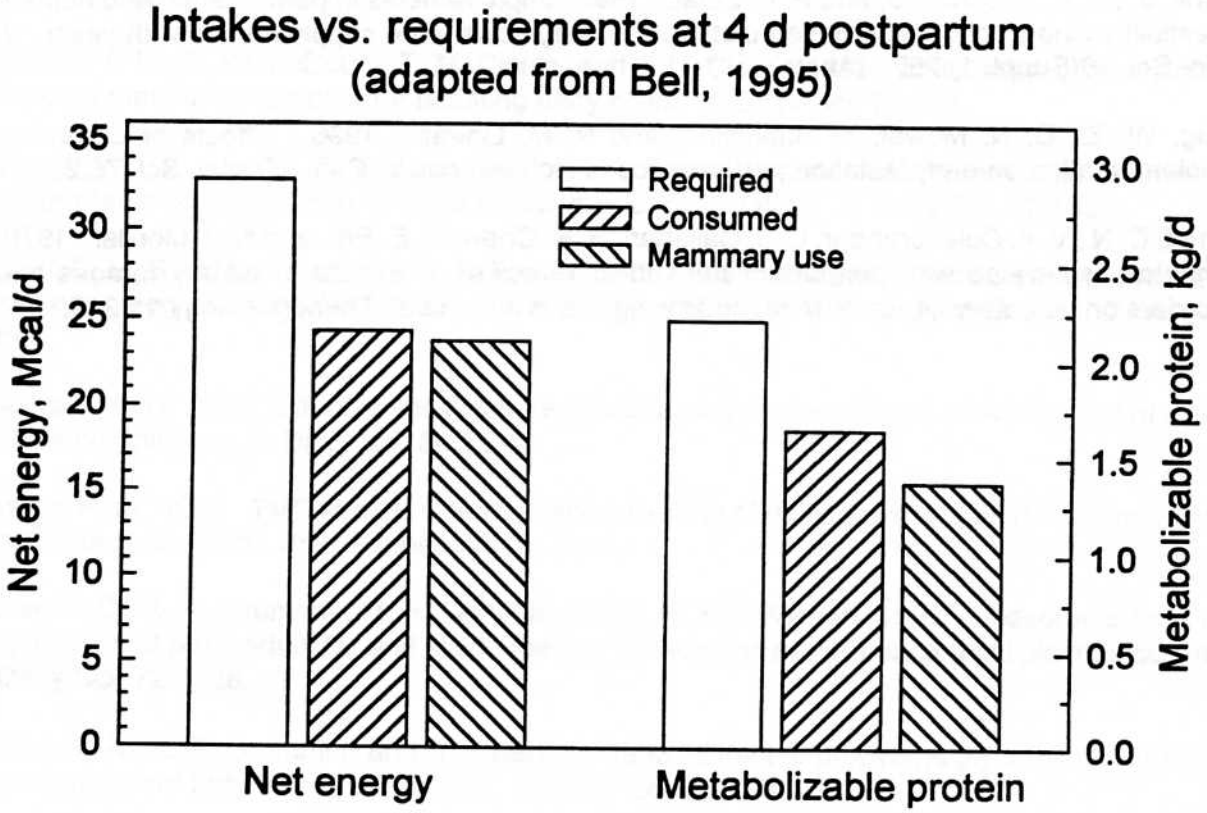

Figure 1. Data adapted from Bell (1995) showing the amounts of net energy (NE_L) and metabolizable protein required and consumed by dairy cows, and the amounts used by the mammary gland of those cows, on the fourth day after calving. From Drackley (1996).

Table 1. Predicted dry matter intake for Holstein cows and first-calf heifers during the first five weeks after calving[1].

Week after calving	Cows	First-calf heifers
	(Predicted dry matter intake, lbs/day)	
1	36.5	31.0
2	42.5	35.0
3	46.5	38.0
4	49.0	40.0
5	52.5	41.5

[1]Assumes: 1400 lb Holstein cows losing 70 lbs of body weight over the five-week period and producing 90 lbs/day of 4% fat-corrected milk; 1200 lb heifers losing 40 lbs of body weight over the five-week period and producing 65 lbs of 4% fat-corrected milk. Calculated by Shaver (1993) from equations developed by Kertz et al. (1991).

Table 2. Effect of the interval during the night without concentrate on metabolic characteristics and production of dairy cows (from Bertoni et al., 1994).

	Longest interval without concentrate[1]		
Variable	5 hours	8.5 hours	*P*
Blood metabolites, millimolar			
Glucose	3.55	3.07	0.01
Nonesterified fatty acids	0.54	1.11	0.01
β-Hydroxybutyrate	0.76	1.65	0.001
Urea	4.23	5.44	0.001
Milk yield, lb/day	65.8	65.6	NS
Dry matter intake, lb/d	41.8	37.4	0.05

[1]Forages were offered at 0700 and 1500 hours; concentrates were offered 8 times daily. Values are means for the first 4 weeks of lactation.

Table 3. Example of the effects of pre-calving depression of dry matter intake on nutrient specifications required in far-off and close-up rations[1].

Item	Far-off dry cow	Close-up dry cow
Body weight (BW), lbs	1400	1500
Dry matter intake, % of BW	1.8	1.5
Dry matter intake, lbs/day	25.2	22.5
NE_L Required, Mcal/day	13.16	13.86
NE_L Needed in ration, Mcal/lb	0.52	0.62
Crude protein required, lbs	2.78	2.92
Crude protein needed in ration, %	11.0	13.0

[1]Requirements taken from NRC (1989).

Table 4. Ingredient and chemical composition of diets fed to dry cows in study of Grum et al. (1996b).

Composition	Diet[1]		
	Control	HF	HG
Ingredient	——— (% of dry matter) ———		
Oat hay, chopped	69.75	79.35	51.00
Ground shelled corn	26.00	9.00	42.60
Soybean meal	3.00	4.00	4.60
Liquid fat[2]	. . .	6.50	. . .
Mineral and vitamin mix[3]	0.95	0.95	1.30
Limestone	0.30	0.20	0.50
Chemical			
Crude protein	12.7	12.8	13.2
Acid detergent fiber	35.5	38.5	27.2
Neutral detergent fiber	60.3	62.2	50.0
Ether extract	2.3	6.7	2.2
NE_L, Mcal/lb of DM	0.58	0.65	0.65

[1]HF = High fat; HG = high grain.

[2]Qual-Fat® (National By-Products, Inc., Mason City, IL).

[3]Contained 5.0% Mg, 7.5% K, 10.0% S, 3.0% Zn, 3.0% Mn, 2.0% Fe, 0.5% Cu, 0.015% Se, 0.004% Co, 0.025% I, 2200 IU/g of vitamin A, 662 IU/g of vitamin D, and 8 IU/g of vitamin E.