Dietary Energy Density for the Close-Up Dry Cow – Postpartum Performance

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Introduction

The transition period for dairy cows is generally defined as the time period from three weeks prior to parturition through three weeks after parturition. It is now recognized that defining and meeting the nutritional requirements of the transition dairy cow can greatly impact animal health, production in the ensuing lactation, overall longevity, and animal well-being (NRC, 2001). Nutrition and management during the transition period are essential in determining the profitability of the cow for the rest of her lactation. An inadequate transition program may result in cows having inconsistent feed intakes after calving, and metabolic diseases during the transition into lactation. Inadequate nutrients provided to the transition cow can result in increased costs for veterinary treatment and loss of production potential. Problems during the transition period often result in the loss of 10 to 20 lbs of peak milk, which translates into economic losses up to $600 for that lactation. To maximize productivity and ensure successful reproduction, rations fed during this time need to be nutrient dense and allow for proper transitioning of the diet to the lactating cow ration. Maximizing prepartum and postpartum dry matter intake is an important key to successful transition cow management.

Dry cow nutrition has been an active area of research over the last two decades with an intensive interest in management of cows during the transition period. The intense research effort has resulted in better understanding of the biology of cows and some insight into how to feed cows during the close-up dry period. However, the lack of repeatable success with close-up dry period nutrition programs in decreasing the occurrence of health disorders and increasing subsequent milk production has been a concern to nutritionists and producers attempting to implement various nutritional programs. Many nutritional strategies have come and gone and very new concepts have really taken on to be "the" recommended program for prepartum rations. This paper will highlight some of the current concepts of feeding dry cows. There has been renewed interest in low energy, high forage diets for cows during the dry period. Systems being implemented include high-straw, one-group total-mixed rations (TMR) for the entire dry period, lower inclusion rates of straw with other forages in one- or two-

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group systems, use of high-fiber by-product feeds to lower starch content; and a variety of other combinations and modifications.

Many research groups including ours are interested in the potential of these approaches to decrease calving-related health problems. Field application and testing of different approaches has provided insight as well, but there is much we need to learn yet. The objective of this article is to summarize the current research and provide some recommendations based on research and field experiences as to how prepartum feeding impacts postpartum health and performance.

Economic Impact

Feed-related costs typically construe 50-70% of the costs of production on a dairy farm, while the costs associated with a single health problem often are never fully recovered. Because the transition period (three weeks prepartum to three weeks postpartum) has the most impact on health, production and reproduction, the greatest marginal return for an investment that improves dairy cow profitability will occur for changes made during this time. The transition to lactation underscores the importance of gluconeogenesis in ruminants as hypoglycemia, ketosis, and related metabolic disorders are often observed when gluconeogenic capacity fails to adapt to the increased demands for glucose to support lactose synthesis and mammary metabolism. Ketosis is accompanied by fatty liver and cows that develop fatty liver and ketosis have reduced feed intake, lower gluconeogenic capacity (Grummer, 1995), lower milk production, and an increased risk for developing other metabolic and infectious diseases (Curtis et al., 1985). It has been estimated that an incident of ketosis costs the dairy producer $140/cow in treatment costs. Given a ketosis incidence rate of 17% in US cattle (Gillund et al, 2001), a producer milking 120 cows would lose $2,520 annually to clinical ketosis. Subclinical ketosis costs approximately $78/case (Geishauser et al, 2000). Additional losses are realized through lost milk production potential. Reducing subclinical ketosis and fatty liver such that cows produce a minimum of 1 lb more milk at peak lactation would result in an additional $2,880 of income. In addition, ketosis increases the risks of developing other metabolic diseases such as displaced abomasum ($334/case; Shaver et al, 1997), retained placenta ($319/case; Enevoldsen et al, 1995), and mastitis ($200/case; Nickerson, 1991) and other metabolic problems. Clearly, feeding management strategies that reduce clinical and subclinical ketosis will directly benefit dairy farm profitability, enhance animal well being, and improve cow longevity.

Factors impacting nutrient needs of the transition cow

Does ruminal capacity affect prepartum intake depression?

The fermentative capacity of the rumen has not adequately been characterized through the dry period to lactation. Understanding the dynamics of rumen digestion is critical to developing a mechanistic approach to predicting the nutritive value of feeds for transition dairy cows. During late gestation it has been thought that cows reduce dry matter intake as a consequence of constraints in rumen fill and digestion. This reduction in intake results in the mobilization of body fat and energy stores to meet tissue energy demands. The combination of these factors often leads to fatty liver and other problems. Increasing the supply of glucogenic precursors, such as propionate, acts to minimize the negative impact of reduced feed intake during the transition period (Dann et al, 1999). Likewise increasing the energy density of diets for late-gestation dairy cows reduces fatty liver and improves lactation performance (Minor et al., 1998). However, diet modifications that increase energy density through inclusion of rapidly fermentable carbohydrates, such as starch, may increase the incidence of displaced abomasums, acidosis (Penner et al, 2007), and result in over conditioned cows.

Hartnell and Satter (1979) demonstrated that there were no differences in ruminal fill, digesta capacity, or ruminal retention time in prepartum vs. postpartum dairy cows. Park et al. (2001) most recently demonstrated by measuring ruminal water holding capacity at various times prepartum and postpartum that physical capacity of the rumen during this time period does not contribute to prepartum intake depression. It becomes very clear as more information of this nature becomes available that to some extent the role of physical constraints has been overemphasized in ruminants and those metabolic and endocrine changes in late pregnancy and early lactation play an important role in prepartum intake reduction (Ingvartsen et al., 1999). Actually this intake reduction prepartum is not unique to ruminant animals. This also occurs in rats offered a nutritious diet, even though food consumption was substantially less than what would be expected as their physical capacity (Peterson and Baumguardt, 1976). Some researchers have demonstrated that hypophagia may play an important role in early host defense mechanisms (Murray and Murray, 1979). It is known that during infections, cytokines are released that may severely reduce intake. Additionally, feedback signals from the oxidation of nonesterified fatty acids (NEFA) are speculated to down regulate intake in late pregnancy and early lactation when mobilization is high (Ingvartsen and Andersen, 2000). We have shown that cows have higher NEFA in blood at the same time as feed intake is reduced and the effect is similar whether this occurs prepartum or postpartum (Figure 1). Before trying to improve feed management, it is important that we have a better understanding of intake regulation in the periparturient animal.

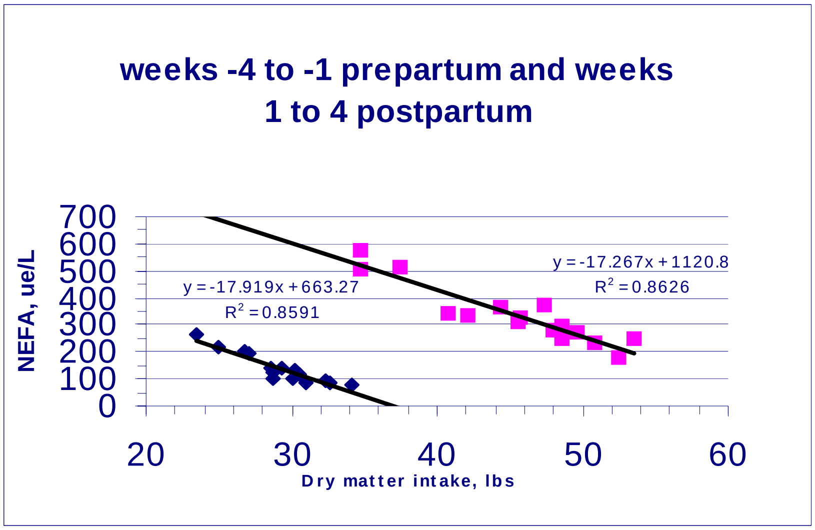

Figure 1. Effect of NEFA concentrations on DMI prepartum and postpartum. (Vallimont et al, 2001).

Prepartum DMI effects on postpartum DMI: is it important?

There appears to be some evidence now 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 day 21 through day 1 prepartum and the change in DMI between day 21 and day 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 day to 1 day 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 prepare and adapt cows to negative energy balance. 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). Therefore these cows actually had a rebound in DMI postpartum. Feed-restricted cows seemed to have greater insulin sensitivity (Holtenius et al., 2003) and reduced peripartal NEFA curves compared with those fed for ad libitum intake (Douglas et al., 1998; Holcomb et al., 2001; Holtenius et al., 2003).

Several studies conducted at Penn State University have examined animal performance of cows fed restricted intake diets at 1.5% of body weight (DMI of 19 lb/d) for 4 weeks prior to calving versus free-choice feeding where DMI was as high as 2.7% of body weight (DMI of 35 lb/d). The take-home message from these experiments was as long as the rations were properly balanced and managed, DMI postpartum and animal health was not compromised. These data and those mentioned above are interesting, but all experiments were conducted with cows that were individually housed and fed. In a practical setting achieving uniform restricted intake in the typical group-fed situation where social interactions and competition will predominate will be difficult to achieve.

How long does it take for animals to adapt to dietary changes?

Approximately 5 weeks are required to change the physiological set point of ruminant animals in response to alterations in nutritional status (Koong et al, 1982). Rumen, intestines, and liver size differ significantly from 3 weeks prepartum compared with 3 weeks postpartum (Reynolds et al., 2000) and blood flow through the portal drained viscera is positively correlated with energy intake (Huntington, 1990). Koong and Ferrell (1990) demonstrated that fasting heat production could differ up to 40% for animals of the same age and weight, but with different nutritional backgrounds. Huntington et al. (1988) demonstrated the oxygen consumption by the portal drained viscera, as a percentage of whole animal oxygen consumption was 4% greater for cows fed orchardgrass silage compared to alfalfa silage. Finnegan et al. (2001) most recently demonstrated a role for the gastrointestinal tract contributing to higher thermogenesis observed in ruminants fed forage as opposed to concentrate diets. Taken together these data suggest a minimum of 5 weeks of feeding may be required to establish a new metabolic plateau for liver and intestinal tissues in response to diet. Therefore, the duration of feeding a nutrient dense diet may dictate the adaptive response in gut and liver and their capacity to meet the demands for milk production in the ensuing lactation.

There are many physiological challenges prepartum where we clearly lack adequate information to help guide us in nutritional strategies during the transition period. These include the importance of acclimation of microbial populations to the lactating cow diet, maintaining microbial protein synthesis, assuring maximal absorptive capacity of the ruminal epithelium, liver and gut function set points, quantity of adequate glucogenic precursors, and the additional nutrients needed to meet the demands for protein and energy for growth of the mammary gland.

Feeding strategies and management of dry cows

Nutritional strategies

The primary goal of nutritional management strategies during the transition period should be to support the dam, fetus, uterine, and mammary tissues. The Dairy NRC committee (2001) recommended that a diet containing approximately 0.57 Mcal/lb of NEL be fed from dry off until approximately 21 d before calving and that a diet containing 0.70 to 0.73 Mcal/lb of NEL 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 gain during the dry period. Recent data (Dann et al., 2006) 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., 2004; Corbett, 2002; Mashek and Beede, 2001). Recent data (Contreras et al., 2004) 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.

Evaluation of dietary strategies

A great deal of research has focused on increasing the energy content of the close-up diet by varying the nonfiber carbohydrate (NFC) content of the diet. 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.

Mashek and Beede (2001) reported no effect of length of duration that cows were fed a close up dry cow diet on milk production. In a trial feeding a 60:40 (DM basis) of grass silage with barley straw ad libitum, grass silage ad libitum, or 0.5 kg/d of prairie meal with grass silage ad libitum for six weeks prior to parturition, no effect of diet on milk yield was observed (Dewhurst et al., 2000). Holcomb et al. (2001) fed diets high (70%) or low (28%) in forage either restricted or ad libitum for four weeks prior to parturition and reported no significant effects of forage percentage during the prepartum period on milk yield. VandeHaar et al. (1999) fed diets varying in both protein and energy for 25 days prior to parturition and again reported no effect of diet composition on milk or component yield during lactation. Keady et al. (2001) supplemented grass silage based diets with 0 or 5 kg/d of concentrates for four weeks prior to calving and found no effect of treatment on milk and milk protein yield, while milk fat increased significantly with concentrate feeding. Holcomb et al. (2001) reported no advantage of high DMI prepartum vs. restricted diets on milk production.

Although the range of NFC concentrations in many experiments were 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. 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.

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 dietary 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.

Application of low energy diets

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. However field reports have indicated success in response to feeding a transition diet containing chopped straw (i.e., 8 to 10 lbs of DM) and have consistently observed reduction in the incidence of postpartum displaced abomasum. The high degree of bulkiness should ensure high rumen fill and thereby decreasing the risk of displaced abomasum and potentially limiting energy intake. The rumen of these cows remains full during transition into lactation with these high straw diets likely for a week. During this time when DMI might be lower there appears to be less opportunity for these cows to displace. 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 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.

Most recently Dann et al (2006) demonstrated that plane of nutrition during the far-off dry period plays a significant role in periparturient metabolism, regardless of the close-up ration. Cows that were overfed (150% of NRC) during the far-off period had higher serum concentrations of NEFA and BHBA and lost more BW during the close-up period. These same animals had the highest serum concentrations of NEFA and BHBA and the lowest DMI and energy balance during the first 10 days in milk. The carryover effect of the far-off period feeding diminished as lactation progressed. Milk yield was not affected by the far-off period feeding. Cows that were restricted in DMI during the close-up period had a lower energy balance, lower serum concentrations of glucose and insulin, and a higher serum concentration of NEFA during the close-up period but had a higher energy balance during the first 56 DIM. Milk yield was not affected by the close-up period feeding. The serum NEFA concentration and liver total lipid concentrations were highest for cows fed the combination of 150% of NRC and restricted close-up. Based on the results of this study overfeeding during the far-off period combined with underfeeding during the close-up period was shown to have a negative effect on prepartum energy metabolism. These findings may be applicable to situations in which DMI in close-up groups is decreased by overcrowding or other management limitations. Thus, overfeeding during the early dry period may play a greater role in development of postpartum health disorders than markedly different close-up nutrition programs.

How low-energy dry cow diets might work

It is likely that decreasing dietary energy density in the far-off dry period to near NRC recommendations (about 0.57 Mcal NEL per pound of DM) may help to decrease health problems in several ways. First, the addition of indigestible or slowly digestible fiber sources (straw, cottonseed hulls, or corn stalks) maintains rumen health, fill, and function, and may help to prevent displaced abomasum around calving.

Excessive energy intake relative to requirements for a prolonged period seems to increase insulin resistance and other changes similar to those in obesity and Type II diabetes in humans and other animals. Dann et al (2006) demonstrated that when cows were allowed free access to the moderate energy diet, they had higher insulin concentrations while maintaining similar glucose concentrations, an indicator of insulin resistance. Others have provided more direct evidence of insulin resistance caused by prolonged over consumption of energy (Holtenius et al., 2003). By lowering energy intake in the dry period, post-calving appetite may be improved, mobilization of body fat stores may be decreased, and fat accumulation in the liver may be decreased (Drackley, 1999; Drackley et al., 2001).

Cows during the dry period still can easily meet their energy needs (about 14 Mcal of NE_L per day for a typical Holstein cow) when fed a palatable low-energy diet; for example, cows would need to consume only 23.7 lb DM per day of a diet containing 0.59 Mcal/lb DM to meet energy requirements. Ingredients that would work well in decreasing dry period dietary energy density also tend to be lower in potassium content. By lowering the potassium density of the diet, problems with periparturient hypocalcemia also may be lessened. It is important to understand that in all of these studies, the outcome of the prepartum diet is more likely its effects on metabolic disease which is much more difficult to measure unless hundreds of animals are evaluated.

Effect of body condition

Heavier cows experience a greater decrease in DMI prior to calving than do cows of thin body condition. In situations in which cows are fat at dry off, restricting intakes during the prepartum period would be beneficial to avoid accumulating more body condition. However there may be increased risk for metabolic disorders after calving such as ketosis, displaced abomasum, and fatty liver. It is clear that over conditioned cows (>4.0 on a 5.0 scale) have reduced intakes after calving and are more prone to fatty liver disease and ketosis (Fronk et al, 1980). In a well-managed, high producing herd, Waltner et al (1993) found that FCM in the first 90 days of lactation was maximized when body condition score was 3.5 at calving. Putnam et al. (1997) demonstrated that cows with BCS > 3.25 prepartum had higher NEFA and BHBA concentrations, and produced 2.5 kg/d less milk the first 30 days of lactation than cows with BCS < 3.25. This is consistent with on-farm studies conducted recently by researchers at Cornell University. In a study conducted by Michelone et al. (1999) prepartum NEFA concentrations averaged 151.8 ± 18.3 µEq/L and BCS averaged 3.28 ± 0.08 in comparison to the study conducted by Putnam et al (1999) where NEFA concentrations averaged 388.5 ± 71 µEq/L and BCS averaged 3.68 ± 0.11. Incidence of subclinical and clinical ketosis was 20% in the study of Putnam et al (1999) and 2% in the study conducted by Michelone et al (1999). Both of these studies were conducted at restricted intake to 1.5% of BW and fed similar diets indicating that body condition was critical in predisposing the fatter cows to metabolic disease.

The bottom line is that heavier cows lose more body condition after calving and have more difficulty getting bred back. It is recommended to begin feeding management decisions for fat cows approximately 60 to 45 days prior to dry-off. If more than 10% of late lactation cows are over-conditioned (BCS > 3.5), a change is warranted. Some options include feeding a low group TMR, restrict intake of a one group TMR to the tail-enders, include NFFS in place of high energy dense feeds, or feed a low quality forage.

Challenges to current dry cow feeding and management concepts

Practical decisions made regarding feeding cows during the dry period are simple. 1) The cow is not lactating therefore she does not need a nutrient dense ration as when she is lactating. However, during the last 6-8 weeks prior to calving the fetus is growing at its most rapid rate and has a tremendous demand for glucogenic precursors. It is also the time period that the cow is manufacturing immunoglobulins necessary for the calf at birth. It has been demonstrated that poor nutrition impacts the composition and quantity of immunoglobulins synthesized. The mammary gland as discussed previously also requires nutrients in preparation for lactogenesis. 2) Since the cow has reduced nutrient demands she can be fed cheaper feed sources and/or lower quality forage. It has not been demonstrated that all physiological aspects of the cow's nutrient demands are reduced during this time period. The cow is most immunocompromised at this time and exposure to mycotoxins and inconsistent nutrients as found in poor quality forages is least desired during this time period. 3) The dry cow can be brought to another facility, needs less oversight and therefore less labor. This is the time period when observation is critical especially regarding the body condition of the animal and her appetite. Physical facilities and cow comfort during this time period is also critical. Buelow (1998) demonstrated that dry cows are more sensitive to overcrowding with an 11% decrease in DMI when numbers went from 88 to 93% of capacity in a headlock pen. 4) Use of a steam-up ration 2-3 weeks prior to calving. Many times the lactating cow ration is used without attention to differences in mineral requirements between pre and postpartum animals. In addition, as discussed previously, 2 to 3 weeks is not adequate time for liver and intestinal enzymes to adjust to the prepartum and postpartum rations.

Is an early and close up ration necessary for dry cows? Can a one group total mixed ration (TMR) be fed during the dry period?

Many producers are successfully feeding a one group TMR during the entire dry period. In a recently completed study (Ordway et al., 2002) we demonstrated that cows provided corn silage-based rations with a portion of the fiber coming from NFFS had higher DMI prepartum in comparison to conventionally-fed dry cows. These diets were based on corn silage as the primary forage source (50% of ration DM), approximately 20% of the ration DM coming from NFFS such as CSH, soyhulls, and corn cobs, with the remainder from soybean meal, molasses, corn, distillers, and vitamins and minerals. Cows consumed on average 6.5 lb/d more DMI compared to the last six prepartum studies we have conducted feeding conventional dry cow rations (~70% of DM from forage) during the last 4 weeks prepartum. Cows were provided the ration the entire dry period and did not gain any additional body condition compared to cows fed a conventional high forage ration. In addition, cows averaged 40 lb/d of DMI the first two weeks of lactation with minimal health problems and peaked with an average of 105 lb/d of milk at 5 weeks postpartum. We conducted a pen-feeding study with 36 animals half of which were heifers evaluating a conventional dry cow ration with one formulated to contain ~35% NFFS fed the entire dry period. All cows averaged 95 lb/d of milk the first 7 weeks of lactation; however mature cows produced 6.5 lb/d more milk when provided the NFFS-based ration prepartum and had a lower incidence of metabolic problems. The cost associated with feeding one ration throughout the entire dry period is easily offset when considering the costs associated with the treatment and lost production for one case of ketosis.

In any dry cow feeding program what is critical is that ration changes are not drastic. The fresh cow ration should be intermediate between the close up ration and the fresh group ration. A shift should not be greater than a 10% increase in any nutrient when transitioning cows prepartum to the lactating cow ration (Chandler, 1995). For example, if the prepartum close-up ration is 0.70 NE_l Mcal/lb then the immediate fresh ration should be no greater than 0.77 NE_l Mcal /lb DM. It is recommended that the dry cow ration have an energy density in the range of 0.68 to 0.72 Mcal NE_l/lb DM, CP in the range of 13-14%, metabolizable protein 1100 to 1200 grams, NFC between 33 to 38%, and NDF >32%.

Nutrition and management during the transition period are essential in determining the profitability of the cow for the rest of her lactation. Stimulation and maintenance of DMI around calving is essential to ensure a high level of productivity and healthy cows. Proper formulation of rations for protein, energy density, fiber, and nonfiber carbohydrates will help to increase intake around calving along with management of body condition, cow comfort, and consistent and high quality forages will assure an excellent transition program for the high producing dairy cow.

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