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Feeding Transition Cows: An Update and Re-Interpretation

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INTRODUCTION

Too many dairy operations continue to struggle with a high incidence of metabolic disorders and infectious diseases around calving. Transition health problems have a large negative effect on profitability through increased veterinary expenses, decreased milk production, impaired reproductive performance, and premature culling or death. The transition period has been the subject of intense research and field emphasis, yet practical management strategies to minimize health problems while still promoting high milk production have remained controversial. Although not the focus of this paper, aspects of management such as overcrowding, feeding space, cow comfort, and movement among groups are emerging as likely the most important determinants of transition success (Cook and Nordlund, 2004; Cook, 2007).

Periparturient diseases and disorders are strongly associated with negative energy balance after calving. Over the last 15 – 20 years, a great deal of emphasis has been placed on maximizing energy intake during the close-up or pre-fresh period in an attempt to improve energy balance. This approach was designed on the basis of research showing advantages in adaptation of the rumen microbial population and rumen papillae to higher nutrient diets fed after calving, decreased body fat mobilization and fat deposition in liver, and maintenance of blood calcium concentrations. Although each of these ideas were sound and based on good research data, the ability of higher-energy close-up or "steam-up" diets to minimize production diseases in research trials and field experience has been disappointing. It has now become clear that this approach does not lead to improved postpartum energy balance or transition outcomes, despite increased energy intakes before calving.

Over the last decade, our research group has studied the effects and potential benefits of controlling energy intake during the dry period. Although our initial reports (Douglas et al., 1998) were met with a great deal of skepticism, these concepts now are being widely applied worldwide with considerable success. This paper summarizes the logic of controlling energy intake during the dry period and discusses methods for practical implementation.

IMPORTANT ASPECTS OF PERIPARTURIENT PHYSIOLOGY

Negative energy balance after calving is driven mainly by dry matter intake (**DMI**), and thus energy intake, and is poorly related to milk production or milk energy balance (Zurek et al., 1995; Drackley et al., 2005). In response to negative energy balance, cows mobilize stored triglycerides in adipose tissues as an energy supply for milk production and maintenance functions. Glycerol released from lipolysis is used by the liver for gluconeogenesis. The fatty acids released circulate as nonesterified fatty acids (**NEFA**) and are distributed with blood flow to all tissues of the body (Drackley et al., 2001). When NEFA concentrations are elevated during early lactation, the mammary gland takes them up efficiently and converts them to milk fat. As a consequence, high milk fat concentrations, or high milk ratios of fat to protein, are useful indicators of ketosis in dairy cows.

The liver receives about 1/3 of all blood flow from the heart. Consequently, the liver is flooded with NEFA when blood concentrations increase around calving. The liver takes up NEFA in proportion to their concentration in blood. Within liver cells, NEFA can be 1) oxidized to CO_2 with the generation of ATP for the liver's energy needs, 2) partially oxidized to the ketone bodies β-hydroxybutyrate (**BHBA**) and acetoacetate, which results in ATP for the liver and a water-soluble energy source for muscle and heart, or 3) re-converted to triglycerides. Because ruminant animals are unable to effectively move triglycerides out of the liver as very-low density lipoproteins, triglycerides can accumulate and cause fatty liver. Increased ketone body production can result in ketosis if severe (Drackley et al., 2001).

Lipolysis (fat breakdown) in adipose tissue is stimulated mainly by the sympathetic nervous system in the presence of low insulin concentrations. The sympathetic nervous system responds to energy shortage or chronic stressors with greater activity. Although stressors and severe limitations in feed intake can lead to negative energy balance before calving, the degree is much less than what occurs following parturition. To prevent disease problems associated with negative energy balance, therefore, management and nutrition practices should focus on minimizing the presence of stressors and the extent and duration of postpartal negative energy balance to minimize the mobilization of NEFA from adipose tissue triglycerides around calving. Key focus areas are in decreasing stressors in the cows' environment and providing pre-calving diets that promote consistent and adequate energy intakes.

CONTROLLING ENERGY INTAKE DURING THE DRY PERIOD

As we have argued elsewhere, the simplest and most easily defended principle of nutrition for dairy cows during the dry period and transition is to feed to meet but not greatly exceed the cows' requirements (Drackley and Dann, 2008). This concept in many ways is nothing new, as it centers on formulating dry cow rations to dietary energy densities that were established many years ago by the National Research Council (**NRC**). Rethinking what these data and previous knowledge tell us about dry cows has led us to a new interpretation relative to the existing dogma, and to develop practical systems suitable for modern dairy management practices on both small and large dairies.

Our research group has investigated whether controlling energy intake during the dry period might lead to better transition success (Grum et al., 1996; Drackley, 1999; Drackley et al., 2001, 2005; Dann et al., 2005, 2006; Douglas et al., 2006; Loor et al., 2005, 2006). Our research drew from earlier reports that limiting nutrient intakes to requirements of the cows was a preferable strategy to overfeeding (Kunz et al., 1985). We also relied on our ideas and observations as well as field experiences by others. The data we have collected demonstrate that cows fed even moderate-energy diets (0.68 – 0.73 Mcal NE_L/lb DM) will easily consume 40 – 80% more NE_L than required during both far-off and close-up periods (Dann et al., 2005, 2006; Douglas et al., 2006). Cows in these studies were all less than 3.5 body condition score at dry-off, were housed in individual stalls, and were fed diets based on corn silage, alfalfa silage, and alfalfa hay with some concentrate supplementation. We have no evidence that the extra energy and nutrient intake was beneficial in any way. More importantly, our data indicate that allowing cows to over-consume energy even to this degree may predispose them to health problems during the transition period if they face stressors or challenges that limit feed intake.

We have collected a variety of data indicating that prolonged over-consumption of energy during the dry period can result in poorer transitions. These data include whole-animal responses important to dairy producers such as lower post-calving DMI and slower starts in milk production (Douglas et al., 2006; Dann et al., 2006). We also have demonstrated that overfeeding results in negative responses of metabolic indicators, such as higher NEFA in blood and more triglyceride in the liver after calving (Douglas et al., 2006; Janovick Guretzky et al., 2006). From a basic-science standpoint, there are alterations in cellular (Litherland et al., 2003) and gene-level responses (Loor et al., 2005, 2006, 2007) that potentially explain many of the changes at cow level. We have most recently demonstrated that controlling energy intake during the dry period positively affects neutrophil function postpartum (Graugnard et al., 2008) and so may lead to better immune function.

Our data demonstrate that allowing dry cows to consume more energy than required, even if cows do not become noticeably over-conditioned, results in responses that would be typical of overly fat cows. Because energy that cows consume in excess of their requirements must either be dissipated as heat or stored as fat, we speculate that the excess is accumulated preferentially in internal adipose tissue (fat) depots in some cows. Indeed, we have recently demonstrated that moderate overfeeding of non-lactating cows for 57 d leads to greater deposition of fat in visceral adipose tissues (omental, mesenteric, and perirenal) than in cows fed a high-straw diet to control energy intake at requirements (Nikkhah et al., 2009). The NEFA and signaling molecules released by some of these visceral adipose tissues go directly to the liver, which may cause fatty liver, subclinical ketosis, and other secondary problems with liver function. Humans differ in their tendencies to accumulate fat in different locations, and central obesity is a greater risk factor for disease. Similarly, cows might also vary in the degree to which they accumulate fat internally. In many cases, the mechanisms we have been studying in dry cows are similar to those from human medical research on obesity, type II diabetes, and insulin resistance.

Other research groups in the US (Holcomb et al., 2001) and in other countries (Agenas et al., 2003; Kunz et al., 1985; Rukkwamsuk et al., 1998) have reached similar conclusions about the desirability of controlling energy intake during the dry period, requirements of the cows was a preferable strategy to overfeeding (Kunz et al., 1985). We also relied on our ideas and observations as well as field experiences by others. The data we have collected demonstrate that cows fed even moderate-energy diets (0.68 – 0.73 Mcal NE_L/lb DM) will easily consume 40 – 80% more NE_L than required during both far-off and close-up periods (Dann et al., 2005, 2006; Douglas et al., 2006). Cows in these studies were all less than 3.5 body condition score at dry-off, were housed in individual stalls, and were fed diets based on corn silage, alfalfa silage, and alfalfa hay with some concentrate supplementation. We have no evidence that the extra energy and nutrient intake was beneficial in any way. More importantly, our data indicate that allowing cows to over-consume energy even to this degree may predispose them to health problems during the transition period if they face stressors or challenges that limit feed intake.

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STRATEGIES TO CONTROL DRY PERIOD ENERGY INTAKE

In light of the apparent desirability of feeding to allow cows to meet but not greatly exceed their requirements for energy during the dry period, there are at least three approaches that could be implemented to achieve this goal. The first is to feed cows only poor-quality roughages and other dietary ingredients that would minimize the potential for excessive energy intake. This is the concept that was the default management option on many farms several decades ago. However, the dangers are that excessive variation of ingredient quality may promote inconsistent intake of nutrients, that the ration may provide imbalanced nutrient profiles, and that such feeds may be contaminated with molds or toxins. This is not a desirable mindset or approach and it will not be considered further here.

Limit-Feeding Dry Cows

A second and better approach is to formulate a diet of moderate energy density (0.68 – 0.73Mcal NE_L/lb DM) and limit-feed it in amounts of dry matter (**DM**) that would meet the average Holstein cow or heifer requirement of 14 – 15 Mcal daily. Note that we are not advocating limiting cows below their requirements as we have done in some of our experiments (Dann et al., 2005, 2006; Douglas et al., 2006). One study that implemented limit-feeding to requirements found favorable results (Holcumb et al., 2001), whereas a more recent study showed little difference between limit-feeding or ad libitum feeding (Winklemen et al., 2008). It should be noted in the latter study, however, that cow numbers were limited and 3 of 9 cows assigned to the ad libitum (overconsumption) group developed health problems at calving and so did not contribute postpartum data to the evaluation.

Conceptually, limit feeding is a workable method for controlling energy intake. In practice, however, it requires a high level of management to implement successfully. Limit feeding works only where cows are housed individually (rare) or where group-feeding systems allow an abundance of feeding space. Feed must be delivered over bunk space that is adequate to allow all cows access to feed. Implementation requires that dairy producers become as adept at managing feed bunks as beef producers are. The goal is to formulate rations for target DM intakes that would take cows 22 – 23 h/d to consume. In other words, dry cows should be fed to a clean bunk shortly before the next feeding. Given the dynamic nature of cows moving in and out of single-group dry cow pens or close-up pens, and perhaps variable total numbers of cows, management of limit-feeding often is more challenging on dairy farms that in beef feedlots.

High Bulk, Low Energy Diets for Dry Cows

A third solution to the potential for cows to over-consume energy is to formulate rations of relatively low energy density (0.59 – 0.63 Mcal NE_L/lb DM) that cows can consume free choice without greatly exceeding their daily energy requirements. The principle is to feed cows a diet of sufficient fiber (bulk) content that cows will only meet their requirements consuming all the DM they can eat. We have termed this the "Goldilocks diet" (Drackley and Janovick Guretzky, 2007) because the target intake is neither too much nor too little energy, but rather just the right amount to match requirements.

To accomplish the goal of controlled energy intake requires that some ingredient or ingredients of lower energy density be incorporated into diets containing higher-energy ingredients such as corn silage, good quality grass or legume silage, or high quality hay. Cereal straws, particularly wheat straw, are well-suited to dilute the energy density of these higher-energy feeds, especially when corn silage is the predominant forage source available. Lower quality grass hays also may work if processed appropriately, but still may have considerably greater energy value than straw and thus are not as effective in decreasing energy density.

We are aware of no controlled data comparing different types of straw, but it is the general consensus among those who have years of experience using straw that wheat is preferred. Barley straw is a second choice, followed by oat straw. While reasons for these preferences are not entirely clear, wheat straw is more plentiful, is generally fairly uniform in quality, and has a coarse, brittle, and hollow stem that processes easily, is palatable, and seems to promote desirable rumen fermentation conditions. Barley straw lacks some of these characteristics. Oat straw is softer and as a result does not process as uniformly. In addition, oat straw generally is somewhat more digestible and thus has greater energy content.

It is critical that the straw or other roughage actually be consumed in the amounts desired. If cows sort out the straw or other high bulk ingredient, then they will consume too much energy from the other ingredients and the results may be poor. A TMR is by far the best choice for implementing high-straw diets to control energy intake. Very few TMR mixers can incorporate large amounts of straw without pre-chopping and without overly processing other ingredients. Straw may need to be pre-chopped to 2-in or less lengths to avoid sorting by the cows.

ADVANTAGES AND BENEFITS

Based on our research and field observations, adoption of the high-straw, low-energy TMR concept for dry cows might lead to the following benefits:

- Successful implementation of this program essentially eliminates occurrence of displaced abomasum. This may result from the greater rumen fill, which is maintained for some period of time even if cows go off feed for some reason, or from the stabilizing effect on feed intake (Janovick Guretzky et al., 2006).

- Field survey data collected by the Keenan Co. in Europe (courtesy of D. E. Beever, Richard Keenan and Co., Borris, Ireland) indicate strongly positive effects on health. In 277 herds (over 27,000 cows) in the United Kingdom, Ireland, France, and Sweden, changing to the high-straw low-energy TMR system decreased assisted calvings by 53%. In addition, the change decreased milk fevers by 76%, retained placentas by 57%, displaced abomasum 85%, and ketosis by 75%. Using standard values for cost of these problems, the average increase in margin per cow in these herds was $114 just from improved health alone. While these are certainly not controlled research data, they are consistent with the results in our research as well as field observations in the USA.
- The same sources of observational data indicate that body condition, reproductive success, and foot health may be improved in herds struggling with these areas.
- Although data are limited, milk production appears to be similar to results obtained with higher-energy close-up programs. There is some evidence that persistency may be improved, with cows reaching slightly lower and later peak milk. Therefore, producers should be careful to not evaluate the system based on early peaks and should look at total lactation milk yield, daily milk, and, over time, indices of reproduction and other non-milk indicators of economic value.
- Straw and corn silage generally are lower in potassium and thus help control the dietary cation-anion difference (DCAD) without excessive addition of anionic salt mixtures.
- The program may simplify dry cow management and ration composition in many cases.
- Depending on straw cost, rations based on corn silage and straw likely will be no more expensive than the average cost of traditional far-off and close-up diets, and could be cheaper where straw is plentiful. Remember that even when straw appears expensive, it is replacing something else in the diet so marginal cost is the key criterion. Furthermore, total DMI per cow may be lowered by addition of straw, so that feed cost per cow per day can actually be decreased substantially.

SINGLE GROUP DRY COWS

Our most recent research (Janovick Guretzky et al., 2006; Richards et al., 2009) as well as considerable field experience indicates that a single-diet dry cow program can be successful using these principles. Dry matter intakes remain more constant as cows approach calving when fed the high-straw low energy diets (Dann et al., 2006; Janovick Guretzky et al., 2006; Richards et al., 2009) than in cows fed high-energy close-up diets (Grummer et al., 2004). Single-group systems would have the advantage of eliminating one group change, which may decrease social stressors as described by University of Wisconsin researchers (Cook, 2007). Single-group management may work particularly well for producers managing for shorter dry periods. A variation is to maintain far-off and close-up groups, with essentially the same diet for both except that a different concentrate mix or premix is used for the close-ups, which may incorporate anionic salts, extra vitamins and minerals, additional protein, or selected feed additives. The optimal high-forage low-energy dry cow ration will contain the primary forages and grains to be fed in the lactation diet, but diluted with straw or low-quality forage to achieve the desired energy density. In this way, the rumen remains adapted to the types of ingredients to be fed after calving without excessive energy.

If producers desire to maintain the conventional two-group or "steam-up" philosophy for dry cow feeding, our research has shown that the most critical factor is to ensure that the energy density of the far-off dry period diet is decreased to near NRC (2001) recommendations (NE_L of 0.57 − 0.60 Mcal/lb DM) so that cows do not over-consume energy (Dann et al., 2006). In this research, wide extremes in close-up nutrient intake had very little effect compared with the effect of allowing cows to consume excess energy during the far-off period.

We recently completed an experiment designed to determine whether moving dry cows to a higher-energy close-up diet at 3 wk before calving would confer any benefits to cows during the transition compared with a single high-bulk diet fed all the way through to calving (Richards et al., 2009). We also included an overfed group, which received the higher-energy close-up diet during the entire dry period. The overfed group had greater DMI during the dry period but not during lactation; cows gained body condition during the dry period but lost more body condition after calving. Overfed cows had increased fat in the liver, greater and more prolonged increases in NEFA and BHBA after calving, and had greater milk fat production than the other two groups. The single-diet group had the least change in DMI around calving, and the lowest concentration of fat in the liver after calving. Surprisingly, the group provided the close-up diet had fat content in the liver that was intermediate to the single-diet group and the overfed group, but did not have any advantages to the single-diet group. There was little evidence, therefore, that the two-group strategy offered any advantage compared with the single-diet (controlled-energy high-fiber) strategy.

SPECIFICATIONS FOR HIGH BULK DRY PERIOD DIETS

The controlled energy system works best for producers relying on corn silage as the primary forage. Typical rations generally contain roughly one-third of the DM as corn silage, one-third as chopped straw, and the remaining third split between some other hay or silage and a small amount of concentrate to meet protein, mineral, and vitamin needs. The combination of straw and corn silage is complementary for many reasons, including energy content, low potassium contents, starch content, and feeding characteristics.

The NE_L requirement for 1500-lb Holstein cows is between 14 and 15 Mcal per day (NRC, 2001). Some suggested guidelines for formulation of controlled energy diets to meet that requirement are as follows, on a total ration DM basis.

- Dry matter intake: 25 to 27 lb per day. For far-off cows, intakes by individual cows often exceed 30 lb DM per day.
- Energy density: 0.59 – 0.63 Mcal NE_L/lb DM.
- Protein content: 12 to 15% of DM as CP; >1,000 g/day of metabolizable protein

as predicted by the NRC (2001) model or CNCPS/CPM Dairy model. This may require addition of high-RUP sources such as blood meal or heat-treated soybean meal.

- Starch content: 12 to 16% of DM. If starch is poorly fermentable diets should be at the upper limit.
- Forage NDF: 40 to 50% of total DM, or 10 to 12 lb daily (0.7 to 0.8% of body weight). Target the high end of the range if more higher-energy fiber sources (like grass hay or low-quality alfalfa) are used, and the low end of the range if straw is used.
- Total ration DM content: 45 – 48% (add water if necessary). Additional water will help hold the ration together and improve palatability. When ration DM exceeds 55%, DMI will decrease and sorting may increase.
- Follow standard guidelines for mineral and vitamin supplementation. For close-ups, target values are 0.40% magnesium (minimum), 0.35 – 0.40% sulfur, potassium as low as possible, a DCAD of +25 to +50 meq/kg, 0.27 – 0.35% phosphorus, and at least 1,500 IU of vitamin E. Calcium is typically set at about 0.9% of DM. Recent data suggests that calcium does not have to be increased beyond 0.6% of DM (Lean et al., 2006). However, successful situations in the field have ranged from 0.5% to >1% calcium.

As long as the lactation diet is formulated appropriately, there seems to be little difficulty in transitioning to the lactation diet immediately after calving. Many producers have found that inclusion of ½ to 2 lb of chopped straw in the lactation diet improves rumen function and animal performance, particularly when physical fiber is borderline adequate. Addition of the straw postpartum also may help to ease the transition from the lower-energy dry cow diet.

COMMON PROBLEMS IN FIELD IMPLEMENTATION

Three factors are critical to successfully implement this approach: 1) prevention of sorting, 2) ensuring continuous and non-crowded access to the TMR, and 3) careful monitoring of DM content and attention to detail. Where "train-wrecks" have been reported, one or more of these factors has been faulty, not the dietary approach itself.

The straw must be chopped into a particle size that cows will not sort out of the ration. In general, this means less than 2" particles. If the straw is pre-chopped, an appropriate chop is indicated by having about 1/3 of the particles in each of the three fractions of the Penn State shaker box. Because of the bulky nature of straw and the resulting TMR, producers may think that cows are sorting excessively when they are not. To verify that cows are not sorting, the feed refusals should be monitored carefully and compared to the original TMR. One simple way to evaluate sorting is to shake out the TMR with the Penn State box and then repeat the analysis on the feed refusals the next day. Results should not differ by more than 10% from TMR to refusal. Another way to monitor sorting is to collect samples of the feed refusal from several areas of the feedline and have it analyzed for the same chemical components as the TMR fed. Again, composition of NDF, CP, and minerals should not vary by more than 10% between ration and refusal if cows are not sorting. If cows sort the straw, some cows will consume a higher energy diet than formulated, and some (the more timid cows) will be left with a much lower quality ration than desired. Herds in which sorting is a problem will be characterized by pens of dry cows that range widely in body condition: some will be over-conditioned and some under-conditioned, while of course some may be "just right" (Goldilocks again…).

Another common pitfall is barn design or poor feedbunk management that limits the ability of cows to consume feed ad libitum. Because of the bulky nature of the diet, cows may have to spend more time eating to consume enough feed to meet energy and nutrient requirements. As a result, having adequate bunk space in 6-row barns is problematic. Bunk space must be adequate and feed pushed up frequently. If feed is not pushed up, cows likely will not be able to consume what they need to meet requirements. Other common problems arise when the DM content of straw, hay, and silages changes markedly from assumed values. This may happen, for example, if the straw is rained on or the DM content of silage changes without the feeders knowing it. Changes in DM of the ingredients mean changes in the DM proportions of the total diet unless the mix is corrected. Thus, energy intake may increase or decrease relative to the target, and a rash of calving-related health problems may occur until the situation is corrected.

OTHER CONSIDERATIONS

As mentioned earlier, the combination of straw and corn silage, along with other lactation ration ingredients, works well because of the complementary features of the components in the total diet. Straw has many desirable characteristics that seem to improve health and digestive dynamics in the rumen. The slow digestion and passage rate of straw certainly seems to be important in prevention of DA. Control of energy intake is a critically important factor in maintaining a more constant energy intake during the dry period and in preventing other disorders around calving such as ketosis and fatty liver.

Whether other low-energy ingredients will produce the same desirable results remains uncertain. We are not aware of research that has compared other low-energy ingredients such as poor-quality hay, oat hulls, cottonseed hulls, corn stalks, soybean residue, or flax shives to straw or to conventional rations, although we have anecdotal reports from producers and nutritionists with varying reports of success. With roughage-type materials, the key consideration is uniform processing and palatability so that cows do not sort and the formulated profile of nutrients is actually consumed. Care must be taken to not use moldy or weather-damaged materials or those that have excessive amounts of soil contamination. For concentrate-type or finely ground ingredients, energy content is low but particle size is so small that rate of passage can be too fast, allowing particles to escape more quickly even though they are not digested. In this case, DMI by the cows may increase so that total energy intake still exceeds requirements considerably.

Just because straw or other low-energy ingredients are “low quality” by conventional standards of evaluation based on protein or energy content does not mean that other measures of “quality” can be ignored. Straw or other feeds that are moldy, severely weather-damaged, or have fermented poorly should not be fed to dry cows, especially the close-ups. Producers are advised to lock in supplies of high-quality and consistent straw to minimize these problems. As use of high-straw diets has increased, the relative amount of poor-quality material on the market has increased and farmers forced to “shop the open market” are often confronted with material that should only be used as bedding and not fed.

USE OF FEED ADDITIVES: A NEW INTERPRETATION

Feed additives should be viewed as a means to fine-tune results once the foundation of the base ration has been optimized. Various feed additives may have efficacy in stabilizing the rumen fermentation or the metabolic environment of the cow. A vast majority of the data supporting (or not) the use of feed additives during the transition period has been obtained in diets of more conventional composition (lower-energy far-off diet plus a steam-up or close-up diet). Consequently, whether these additives are beneficial or not when utilizing the controlled-energy strategy is not known. Furthermore, some previous findings may need to be re-interpreted in the light of more current understanding.

As an example, many people question whether monensin (Rumensin) should be used in controlled-energy diets. At first glance its use might seem counter-indicated if we are attempting to limit energy intake. However, in the absence of data to the contrary, my recommendation is to include monensin in all diets. This is to minimize adaptation issues after calving, to promote more stable rumen fermentation, and to improve feed conversion efficiency – a worthy goal whether we are feeding high-quality or low-quality diets. The use of monensin in controlled-energy diets is currently under investigation in our research program.

Several years ago we completed a study to look at the effects of yeast culture (Diamond V XP) in transition rations (Dann et al., 2000). In that study, addition of the yeast culture improved DMI prepartum and tended to result in greater milk production after calving. At the time the study was conducted and published, the prevailing dogma was that we needed to maximize DMI before calving to help prevent extensive body condition loss, fatty livers, and poor starts to lactation. We now might interpret the results of that experiment somewhat differently, however, in the context of controlled energy principles. In that study, the decrease in DMI during the last week before calving was less than the unsupplemented group. Thus, the DMI was more stable across the entire transition, similar to what we observe with the controlled-energy strategy.

CONCLUSIONS

Many different nutrition programs can be successful during the dry period and transition. However, limit-feeding and high-straw (or high-bulk) low-energy rations are exciting for their potential to markedly improve health during the transition period. The key concept is to strive to meet the requirements of cows for energy and all other nutrients, but to not allow cows to exceed their requirements for energy by large amounts for the duration of the dry period. Provided that high-straw low-energy rations are formulated, mixed, and delivered properly, results have been positive and consistent. Research and field observations indicate that the rations result in better energy balance after calving, with subsequent reductions in lipid-related health disorders. Milk production is maintained, and field observations suggest that reproductive success may be improved also, although data are lacking to date. Research is needed to explore other low-energy bulky ingredients as options to straw. Some feed additives may need to be re-evaluated in the context of the controlled-energy approach. For example, yeast culture may be beneficial because of its stabilizing influence on DMI before calving, rather than through promotion of increased DMI.

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