

New Concepts in Nutritional Management of Dry Cows

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■ Take Home Messages

- ▶ Low-energy diets during the early (far-off) dry period show promise in decreasing health problems in fresh cows, and may be more important than typical close-up diets.
- ▶ Addition of chopped straw to a TMR is a popular method to decrease ration energy density while allowing cows to eat all they want.
- ▶ Several factors may impact the success of this approach, and those factors are summarized in this article.

■ Introduction

Dry cow nutrition has been an active area of research over the last half-century. In particular, the last two decades have seen intensive interest in management of cows during the so-called “close-up” or “transition” period, generally considered to be about the last 21 days before calving through 21 days after calving (Grummer, 1995). The intense research effort has resulted in better understanding of the biology of cows during this turbulent period, 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 frustrating and problematic to farmers, nutritionists, and researchers (Drackley, 1999).

It has been said that “there is very little new under the sun”. Indeed, many ideas and practices cycle in and out of popularity, with new applications or new subtleties. The “new concepts” to be discussed in this paper fall into that category. Interest in low energy, high forage diets for cows during the dry period has been renewed in the last two to three years. 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-group systems; use of high-fiber by-product feeds to lower starch content; and a variety of other combinations and modifications.

Our research group is extremely 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 base and provide some recommendations based on research and field experiences.

■ Extent of the Problem

The incidence of periparturient health problems on North American dairy farms today remains sobering. Bench-marking of herd health programs often tends to focus on periparturient disorders separately, for example keeping incidence of clinical milk fevers to less than 5% of all cows calving, etc. However, it has been well established from epidemiological data that the major periparturient disorders (dystocia, milk fever, retained placenta, metritis, ketosis, displaced abomasum, fatty liver, and lameness) are highly interrelated (Curtis et al., 1985; Markusfeld, 1987; Correa et al., 1993; Emanuelson et al., 1993; Peeler et al., 1994). Because of this interrelatedness, and the likelihood that many of these disorders thus share at least some common etiology, using the categories of “healthy” and “problem” cows may provide a better indication of transition period management than focusing on a single disorder. Evidence has accumulated that fatty liver and type II ketosis are not only problems in and of themselves but likely also are major underlying causes of many other periparturient health problems (Grummer, 1993; Drackley et al., 2001; Duffield et al., 2002; Bobe et al., 2004).

From epidemiologic data and field observations, the combined incidence rate for dystocia, milk fever, retained placenta, metritis, ketosis, displaced abomasum, fatty liver, and lameness typically results in only 50% of all cows calving without health problems (Ferguson, 2001). Realistic goals for well-managed farms may be that 60% of cows calve without one or more of these problems (Ferguson, 2001). For example, using the data from Jordan and Fourdraine (1993) for 61 of the top producing herds in the US at that time, the sum of mean incidences reported for milk fever (7.2%), displaced abomasum (3.3%), ketosis (3.7%), nonspecific downer cow syndrome (1.1%), retained placenta (9.0%), uterine infections (12.8%), and dystocia (3.3%) is 40.4%; incidences of lameness were not reported in this survey. Having only one out of every two cows go through the transition without health problems is a major challenge to the sustainability of the dairy industry.

■ Research on Transition Period Nutrition

For the last 10 to 15 years, research has focused on effects of nutritional management during the “close-up” or “pre-fresh” group to decrease incidence of health problems in fresh cows and to allow higher milk production at peak. Much of the emphasis has been on maximizing pre-calving energy intake by pushing for higher dry matter intakes (DMI) and increasing diet energy density through greater rates of concentrate feeding.

The close-up diet approach is today’s version of the “steam-up diet”, a concept that has been in existence since at least 1928 (Boutflour, 1928). It seems logical that use of separate close-up and fresh cow diets, especially when fed as a total mixed ration (TMR), should help cows come onto feed faster and more smoothly after calving, with a lower incidence of postpartum health disorders. The general concept of ration changes during the transition is that nutrient density is increased gradually from that fed to far-off dry cows to the higher nutrient density required for fresh cows. Because DMI of closeup cows may decline by 10 to 30% during the last 7 to 14 days before calving, increased nutrient density may allow maintenance of the same intake *amounts* (pounds or grams per cow per day) of key nutrients such as protein despite lower total feed intake. 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 0.20 Mcal/kg of DM, respectively, in the close-up diet.

Interest in and support for the close-up diet of higher nutrient density (i.e., more cereal grains and less forage) stems from an elegant experiment by Bertics et al. (1992). In that experiment, researchers prevented the normal drop in DMI by force-feeding the refusals into one group of cows fitted with ruminal cannulas. The diet was a 50:50 mixture (DM basis) of corn silage and alfalfa silage, supplemented with vitamins and minerals. Force-fed cows had greater plasma glucose concentrations 2 d before calving and less liver triglyceride accumulation at 1 d after calving and tended ($P < 0.11$) to produce more 3.5% fat-corrected milk (46.1 vs. 41.7 kg/d) during the first 28 d of lactation. Of interest, however, is that by d 14 after calving, force-fed cows had greater plasma NEFA concentrations and by d 28 had similar liver triglyceride concentrations.

While higher-energy close-up diets were implemented enthusiastically by the dairy industry in the US, surprisingly few data are available to support their actual effectiveness in decreasing the incidence of health problems or increasing milk yield. A summary of research conducted on this approach worldwide provides a disappointing view of its potential to improve subsequent DMI and milk production. Health outcomes across studies also provide little evidence for marked improvement. For example, VandeHaar et al. (1999) fed close-up diets with energy densities of 1.30, 1.49, and 1.61 Mcal/kg to cows during the last 28 d before calving. While prepartum DMI tended ($P < 0.11$) to

be increased by about 1.5 kg/d for cows fed the highest energy diet compared with cows fed the lowest energy density, there was no difference in postpartum DMI, milk production, energy balance, or loss in body condition. Although numbers of cows were too small to make reliable inferences about health data, the number of health problems actually was numerically greater for the high density diet (11) than for the lowest density diet (5). Other studies have shown no differences in postpartum responses to widely differing nutrient intakes during the close-up period (e.g., Kunz et al., 1985; Dewhurst et al., 2000; Holcomb et al., 2001; Agenas et al., 2003; Rabelo et al., 2003).

Field experiences have been varied; in some cases, changes in close-diets have resulted in apparent improvements in health or productivity, but in other cases results have been frustrating (Drehmann, 2000). In many cases, the aspects associated with the management of a group of close-up cows have become more important than the particular diet that is fed. Recent observational data from the University of Wisconsin (Nordlund and Oetzel, unpublished) on effects of pen changes and stocking density are particularly exciting in that regard. When producers are struggling with transition-related health problems and the close-up management program is addressed, often more than just diet is changed. Management changes in housing, group size and movement, water availability, and post-fresh monitoring may be as important (or more important) in transition success as the diet itself.

■ What about the Rest of the Dry Period?

Our research group has shared the frustration with inconsistent success of close-up diets. In looking at the scientific literature, one factor that is missing or impossible to interpret in many studies is how cows were handled and fed in the far-off dry period (the first 4 to 6 wk of the dry period) before cows began to receive the close-up diets. We questioned whether far-off nutritional management could impact transition success.

In previous experiments from our group, cows that were limited in energy intake either by being fed a bulky high forage diet supplemented with fat (Grum et al., 1996) or by physically limiting the amount of a TMR offered (Douglas et al., 1998) had less fat accumulation in the liver at calving and higher DMI after calving. Addition of supplemental fat per se did not affect transition outcome appreciably (Douglas et al., 2004). Experiments from other groups in which cows were limited in energy intake before calving are in general agreement with our findings (Kunz et al., 1985; Holcomb et al., 2001; Agenas et al., 2003). Based on these data, along with knowledge from other species, we speculated that prolonged over-consumption of energy relative to requirements during the early dry period would lead to poorer outcomes during the transition period, even in cows that were not overconditioned. We recently completed a large experiment to test this idea (Dann, 2004; Dann et al., 2003a,b).

During the far-off dry period, 74 multiparous Holstein cows were fed a high-forage, low energy diet (1.30 Mcal NE_L/kg) that contained ~26% chopped wheat straw or a moderate energy diet (1.59 Mcal NE_L/kg) based on corn silage and alfalfa silage. The moderate energy diet was fed at either ad libitum intake or restricted intake to supply only 80% of energy requirements during the far-off dry period, similar to our previous experiments (Douglas, 2002). At approximately 3 weeks before calving, half of the cows in each group were switched to a typical close-up diet fed for ad libitum intake and the other half of the cows were fed the same close-up diet at restricted intake (80% of energy requirement). After calving, all cows received the same lactation diet. Diet composition is shown in Table 1.

Table 1. Ingredient and chemical composition of diets fed to multiparous Holstein cows during the dry and lactating periods (Dann, 2004)

Component	Diet			
	Far-off low	Far-off moderate	Close-up	Lactation
	% of DM			
Ingredient				
Alfalfa silage	41.7	26.2	25.1	20.1
Alfalfa hay	...	14.0	13.4	...
Corn silage	21.1	25.5	24.5	28.1
Chopped wheat straw	26.2
Cottonseed	...	4.4	4.2	9.7
Ground shelled corn	7.2	17.2	16.3	25.7
Soybean meal	3.1	5.2
Expeller soybean meal	...	1.7	1.6	5.9
Soybean hulls	...	10.2	9.7	1.5
Minerals and vitamins	0.7	0.8	5.2	3.8
Chemical				
CP	15.8	16.5	15.7	18.1
ADF	31.8	26.1	25.6	19.0
NDF	46.5	38.1	36.9	28.7
NE _L , Mcal/kg	1.30	1.59	1.61	1.77

We found that cows allowed free access to the moderate-energy diet consumed an average of 160% of the National Research Council (NRC, 2001) recommendations for energy (NE_L). It should be noted that this diet was not unusual in its energy density (1.59 Mcal NE_L/kg). Many farms that are using TMR based predominantly on corn or barley silage and chopped alfalfa or grass hay would have similar or even greater energy densities. Cows fed this diet had lower DMI after calving, more negative energy balance, and higher serum concentrations of nonesterified fatty acids (NEFA) and β-hydroxybutyrate (BHBA) compared with cows in which energy intake was

limited during the far-off dry period by feed restriction or straw addition to the diet (Table 2). Consequently, cows that overconsumed energy during the dry period would be more at risk for ketosis, fatty liver, and other health problems.

Table 2. Dry matter intake, energy balance, milk yield, and serum components for multiparous Holstein cows given different far-off and close-up dietary treatments (Dann, 2004)

Variable	Far-off treatments			Close-up treatments	
	Low energy, ad libitum intake	Moderate energy, ad libitum intake	Moderate energy, restricted intake	Ad libitum intake	Restricted intake
# of cows	25	25	24	38	36
1 to 10 days in milk					
DMI, % BW	2.46 ^{abx}	2.16 ^{by}	2.50 ^{ax}	2.38	2.37
DMI, kg	15.9	14.1	15.8	15.2	15.3
Energy balance, %	88 ^{abx}	80 ^{by}	93 ^{ax}	85	90
Milk, kg	29.7	26.0	26.4	27.7	27.0
Serum BHBA, mg/dl	8.13 ^{abx}	9.05 ^{ax}	6.61 ^{by}	8.06	7.80
Serum NEFA, μ Eq/L	787 ^a	792 ^a	627 ^b	783	688
1 to 56 days in milk					
DMI, % BW	3.47	3.26	3.49	3.40	3.41
DMI, kg	21.8	20.5	21.4	21.1	21.4
Energy balance, %	105	102	108	102 ^y	107 ^x
Milk, kg	39.5	36.9	37.0	38.0	37.6
Serum BHBA, mg/dl	5.80	5.82	4.97	5.63	5.44
Serum NEFA, μ Eq/L	336 ^{ab}	376 ^a	296 ^b	356	316

¹ Percent of NE_L requirement.

^{a,b} Subcolumn means within row and treatment category with different superscripts differ ($P < 0.05$).

^{x,y} Subcolumn means within row and treatment category with different superscripts differ ($P < 0.10$).

In contrast, cows with the lower dry period energy balance (those fed the low energy diet ad libitum or the moderate energy diet with restricted intake) during

the far-off dry period had higher DMI and energy balance and lower serum NEFA and BHBA during the first 10 days after calving. Our cows were housed in tie stalls and so intake could be managed easily. Restricted feeding (limiting the amount offered to less than ad libitum intake) will be problematic in group housing situations. Addition of a large amount of chopped wheat straw to the TMR allowed cows to consume the TMR for ad libitum intake, yet controlled energy intake to near NRC recommendations. Interestingly, the close-up dietary treatments (ad libitum or restricted intakes) had no effect on transition cow performance.

Our results were informative in several ways. First, the “best” situation in our experiment was feeding the low energy (high straw) diet during the far-off dry period coupled with ad libitum access to the close-up diet. We believe that many farms struggling with transition health problems might benefit from reducing the energy density of the far-off diet. Second, the “worst” scenarios were the groups that were allowed to over-consume energy in the far-off dry period, regardless of whether they were feed-restricted or allowed ad libitum consumption of the close-up diet. Results for cows that over-consumed energy during the entire dry period (far-off plus close-up) are not surprising relative to previously known effects of overfeeding. However, our results showing the poor outcome caused by overfeeding early followed by feed restriction during the close-up period may help to explain why poor close-up management (overcrowding, poor diets) leads to health problems in the field. Third, cows were in average body condition (3.0 to 3.3 on a 5-point scale) and would not be considered over-conditioned by any measure. Consequently, lower post-calving DMI and other indicators of metabolic imbalance were caused by prolonged consumption of the high-energy diet, not by cows being too fat.

Fourth, the beneficial effects of the low-energy far-off dry period diet diminished as lactation progressed, indicating that the benefits (at least what we could measure in our study) were in getting cows off to a good start. Finally, the two close-up period treatments applied (either ad libitum or restricted feeding of a typical close-up diet) had virtually no effects on any outcome variables that we measured (Table 2). How cows were fed during the far-off dry period was more important.

■ How Low-Energy Dry Cow Diets Might Work

Although we are still studying the biochemical and physiological mechanisms involved, we speculate that decreasing dietary energy density in the far-off dry period to near NRC recommendations (about 1.25 Mcal NE_L per kilogram of DM) may help to decrease health problems in several ways. First, addition of straw to increase bulk and slowly digested fiber maintains rumen health, fill, and function, and may help to prevent displaced abomasum around calving.

Use of low-energy by-product feeds, such as oat hulls, would not have this benefit.

Second, 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 (Lewis et al., 2002). Cows allowed free access to the moderate energy diet in our experiment had higher insulin concentrations in the face of similar glucose concentrations, which is a hallmark of insulin resistance. Others have provided more direct evidence of insulin resistance caused by prolonged overconsumption 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). In our study, capacity of liver tissue for oxidation of fatty acids was greater, and esterification capacity was lower, for cows either feed restricted or fed the low energy diet free choice (Litherland et al., 2003). These changes may prevent development of fatty liver and subclinical ketosis, which are known risk factors for other diseases.

Third, evidence has accumulated that higher-energy diets may allow greater energy intakes during much of the dry period but result in greater decreases in DMI during the last week before calving. Data from our laboratory (Drackley, 2003) and from the University of Wisconsin (Rabelo et al., 2003) indicate that the change in DMI before calving may be more important than the absolute DMI before calving in predicting how well cows eat after calving and how much fat is accumulated in the liver. In other words, it may be better to have a slightly lower DMI that is held more constant than a very high DMI that falls off more sharply before calving. 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 10.8 kg DM per day of a diet containing 1.30 Mcal/kg DM to meet energy requirements.

Fourth, using a bovine cDNA microarray, we have obtained recent evidence that gene expression patterns in the liver at and after calving were altered in response to over- or underconsumption of energy during the dry period (Loor et al., 2004). Differences were found in genes for a wide range of cellular activities, including hormonal signaling, metabolism, protein synthesis, and transport.

Finally, 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.

■ Application of Low-Energy Diets

On the basis of these findings, therefore, we believe that producers struggling with fresh cow problems may want to consider decreasing the energy density of the far-off dry cow diet. Target energy density should be in the range of 1.25 to 1.35 Mcal NE_L/kg DM. One of the most popular and effective methods to lower dry cow ration energy density, or at least the one that generates the most questions, is the addition of chopped straw. We have also used oat hulls as a palatable low-energy ingredient, but supply is variable and unpredictable. Other options may include corn stalks or stalklage.

Here are some factors that we consider important as nutritionists and producers consider implementation of low-energy diets for dry cows. Because of the limited data available, many of these are based on the authors' experiences and observations from the field.

- Although it appears that decreasing ration energy density of far-off dry cow diets may be beneficial, note that we are NOT advocating a return to the dry cow systems of old based on benign neglect and free-choice poor-quality roughage in round bales. We are advocating provision of a low-energy, well-balanced TMR that provides adequate metabolizable protein, minerals, and vitamins but that does not supply excessive energy. These conditions will be hard to control if a TMR cannot be fed. Consumption of individual forages, straw or corn stalks, and concentrates will be variable and unpredictable among cows.
- To adequately lower energy density in far-off dry cow diets based on corn silage and either alfalfa silage or hay may require addition of 20 to 30% of the DM as chopped straw. In our recent experiment straw was incorporated at 26% of the DM, with a resulting energy density of 1.30 Mcal NE_L/kg DM. In practice this may translate to 2 to 4.5 kg of chopped straw daily.
- Straw or corn stalks must be chopped to a small and uniform particle length to be well-incorporated into the diet and not sorted by cows. Particle size of straw should be less than 5 cm – think of it as being able to fit cross-wise inside a cow's mouth! In our experiment, the straw was chopped finely enough that it separated into about one-third each on the two screens and pan of the Penn State particle size separator (Dann, 2004). Most TMR mixers will not adequately decrease straw to this particle size, and will not handle the amount of straw that may be needed in the mix. Thus, for optimal results straw likely will need to be pre-chopped in a forage harvester or tub grinder.
- Based on our data, cows need at least one week to 10 days to fully adapt to these bulky diets. Total DMI may decrease substantially during this adaptation time before increasing again. Consequently, do not introduce a

large amount of straw in the close-up diet without it being in the far-off dry cow diet. If cows are placed on a high straw diet in the close-up period, they may face a declining plane of nutrition leading to calving, particularly those cows with a shorter time in the close-up group. Recent data indicate that this declining DMI may be more likely to result in poor DMI after calving and increased susceptibility to health problems.

- ▶ Questions abound on whether low-quality hay can substitute for straw and provide the same benefits. At this point we are aware of no data to answer this question. However, what is known about digestion characteristics of straw compared with those of grass or alfalfa hay, plus field experience, suggest that straw has different properties from grass or legume hay. The flat, hollow stem and characteristics of the plant cell walls may make straw more conducive to mat formation in the rumen, and to remain in the rumen longer. Such characteristics may be desirable to maintain rumen fill, improve the filtering functions of the fiber mat (which in turn improves digestive efficiency), and prevent displaced abomasums. Straw also seems to be more consistent and uniform than hay. If lowering the energy density is the main goal and ration particle size is otherwise adequate, then low-quality hay may work as long as it is chopped to the same or smaller particle size as the straw and incorporated into a TMR.
- ▶ We are aware of no data that compare straw from different cereals. Field experiences in the US seem to favor wheat straw, with barley second. Oat straw may work adequately but the supply is much more limited in the US. Straw quality likely is important; straw should be clean, dry, and free from mold.
- ▶ Some producers add water to the TMR when adding straw. In our experiment we did not add water and the TMR averaged about 60% DM. Producers may need to experiment with water addition to see if it improves TMR consistency, decreases sorting, or increases DMI.
- ▶ The greater demand for straw in dairy rations has driven up the price of straw in many areas. Based on its nutritive value alone, straw may seem overpriced; however, based on its value as an effective fiber source and possible positive associative effects in the ration, Ohio State University researchers have estimated that straw may be worth as much as \$150 (US) per ton (Eastridge, 2004). If change to a low-energy dry cow diet decreases fresh cow problems, the value of straw would be even more.
- ▶ Our research involved the high straw diet only in the far-off dry period; cows then went to a close-up diet in which chopped alfalfa hay and other ingredients replaced the straw. Likewise, the fresh cow diet did not contain straw. Many producers have successfully implemented the high-straw diet all the way through the dry period, and maintained 0.5 to 1 kg of straw in the fresh cow or lactation diet. Straw can be lower in potassium than legume forages but potassium will accumulate if the soil becomes enriched

with potassium. Whether anionic salts need to be added to the close-up diet to control hypocalcemia will depend on forages available.

- ▶ Diet is only a part of transition success, and a switch to a low-energy dry cow diet will not be the answer if other aspects of far-off and close-up management are lacking. For example, recent observational research at the University of Wisconsin has suggested that moving cows into maternity pens between 3 and 9 days before calving is associated with a greater number of health problems and more cows leaving the herd before 60 days in milk than cows that are either moved to pens right before calving or more than 10 days before calving (G. Oetzel and K. Nordlund, unpublished data, personal communication). Changes in environment are stressful for cows. Overcrowding also is a major problem on many farms; some field research suggests that close-up pen stocking density should be no more than 80% of available stalls.

Much needs to be learned through research and experience about use of high straw or other low-energy diets during the dry period. Ongoing research in our laboratory may help to answer some of those questions, and we look forward to hearing experiences from the field as well.

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