

# Controlled energy diets for dry cows

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## Introduction

Dairy operations large and small continue to be plagued by a high incidence of metabolic disorders and infectious diseases around calving. Turbulent transitions increase health care expenses, decrease milk production, impair reproductive performance, and result in premature culling or death. Farm profitability and animal well-being both suffer. Despite many years of research and field emphasis, practical management strategies to minimize health problems while still promoting high milk production have remained elusive.

Over the last 20 years, it has become common practice to feed rations of higher energy and nutrient density during the close-up (pre-fresh) period, generally beginning around 3 weeks before expected calving. This approach was designed in an effort to adapt the rumen microbial population and rumen papillae to higher nutrient diets fed after calving, decrease body fat mobilization and fat deposition in liver, and control blood calcium concentrations. Although each of these ideas by themselves 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 and frustrating. Overall, research data fail to demonstrate that steam-up diets reliably and repeatedly improve production, body condition, reproduction, or health after calving. Is there a better way?

## Controlled energy during the dry period

Over the last decade, 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; Looor et al., 2005, 2006). Our research drew from both our ideas and observations as well as field experiences by individuals such as Dr. Gordie Jones and Dr. Peter Drehmann. The data we have collected demonstrate that cows fed even moderate-energy diets (0.68 – 0.73 Mcal NE<sub>L</sub>/lb DM) will easily consume 40 – 80% more NE<sub>L</sub> than required during both far-off and close-up periods. Cows in these studies were all less than 3.5 body condition score at dry-off, 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 to this degree may predispose them to health problems during the transition period if they face additional management challenges that create stress responses or limit feed intake.

We have collected a variety of data that indicate 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 dry matter intakes and slower starts in milk production (Douglas et al., 2006; Dann et al., 2006). We also have demonstrated that over-feeding results in negative responses of metabolic indicators, such as higher nonesterified fatty acids (NEFA) in blood and more triglyceride or fat 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) that potentially explain many of the changes at cow level.

Our data demonstrate that over-consumption of energy, even when cows do not become noticeably over-conditioned, results in responses that would be typical of overly fat cows. Because energy that cows consume over their requirements must either be dissipated or stored, we speculate that the excess is accumulated preferentially in internal adipose tissue (fat) depots in some cows. 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. It is well-known that humans differ in their tendencies to accumulate fat in different locations, and that 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 around the US (Holcomb et al., 2001) as well as 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. Our work has extended the ideas to show that over-consumption of energy is common using even typical “safe” dry period diets, and that this may be a predisposing factor to poor health. We also have extended the idea of the high-straw, low-energy ration as a simple and practical approach to achieve the control of energy intake.

### **The “Goldilocks diet” to the rescue?**

Our 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<sub>L</sub>/lb DM) that cows can consume free choice without greatly exceeding their daily energy requirements. It is important to note that we are not proposing to limit energy intake to less than cows’ requirements, but rather to feed them a bulky diet that will only meet their requirements when cows consume all they can eat. In other words, like Goldilocks, we don’t want the cow to consume too much or too little energy, just the right amount to match her 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.

While no controlled data are available comparing different types of straw, 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 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, 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. Some TMR mixers can incorporate straw without pre-chopping and without overly processing other ingredients, but many mixers cannot. It may be necessary to pre-chop the straw to 2-in or less lengths to avoid sorting by the cows.

As discussed in more detail in a later section, properly mixed high-straw low-energy diets can be fed all the way through the dry period. The system can be tailored to a variety of management schemes and preferences.

### **Why do it?**

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.
- Field data collected by the Keenan company in Europe (courtesy of D. E. Beever, Richard Keenan and Co., Borris, Ireland) show impressive results. 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 are improved in herds struggling with these areas.
- Milk production is similar to or greater than results obtained with higher-energy close-up programs. There is some evidence that persistency may be improved, with cows reaching slightly 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 content and thus help to 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 in your area, the ration likely will be no more expensive than the average cost of far-off and close-up diets, and could be cheaper where straw is plentiful.

### **One group or two?**

Our most recent research (Janovick Guretzky et al., 2006) as well as considerable field experience indicates that a single-group 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) than in cows fed high-energy close-up diets (Grummer et al., 2004). Single-group systems have the advantage of eliminating one group change, which may decrease social stressors as described by University of Wisconsin researchers. Single-group management may work particularly well for producers aiming for shorter dry periods.

A slight variation is to maintain far-off and close-up diets, with essentially the same diet for both except that a different premix is used for the close-ups that may incorporate anionic salts, extra vitamins and minerals, additional protein, or selected feed additives. The optimal high-forage low-energy dry cow ration will use most of the forages and grains that will 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 still can be adapted to the types of ingredients to be fed after calving without excessive energy intake during the dry period.

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 over-consume energy during the far-off period.

### **What should the diets look like?**

The system works best for producers who are relying on corn silage as a primary forage. The combination of straw and corn silage is very 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 are as follows.

- Dry matter intake: 25 to 27 lb per day. For far-off cows, intakes often will exceed 30 lb DM per day.
- Energy density: 0.59 – 0.63 Mcal  $NE_L$ /lb DM. This topic is discussed in more detail later.
- Crude protein content: 12 to 14% of DM; >1,000 g/day of metabolizable protein. Use a program such as the NRC 2001 model or CNCPS/CPM Dairy to evaluate metabolizable protein.
- Starch content: 12 to 16% of DM.
- Forage NDF: 40 to 50% of total DM, or 10 to 12 lb daily (0.7 to 0.8% of body weight). The target value should be on the high end of the range if more higher-energy fiber sources (like grass hay or low-quality alfalfa) are used, less if straw is used.
- Total ration DM content: <55% (add water if necessary). Additional water will help hold the ration together and improve palatability.
- 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 near zero or negative, 0.27% phosphorus, and at least 1,500 IU of vitamin E. Recent data suggests that calcium does not have to be increased beyond 0.6% of DM.

An example formulation is included in Table 1, from a recently completed experiment by our group (Janovick Guretzky et al., 2006). The example is for the far-off dry cow group, but the close-up diet was essentially identical except for the addition of anionic salts.

Table 1. Example high-straw, low-energy diet fed during the far-off dry period (Janovick Guretzky et al., 2006)

Item	Amount in ration (dry matter basis)
<b>Ingredients</b>	
Corn silage, %	35.3
Chopped wheat straw, %	31.8
Chopped alfalfa hay, %	17.2
Corn grain, ground, dry, %	3.6
Soybean meal, solvent, 48% CP, %	5.1
SoyPlus, %	4.0
Urea, %	0.9
Minerals and vitamins, %	2.2
<b>Composition</b>	
Forage NDF, %	50.4
NFC, %	25.4
CP, %	14.4
NRC Metabolizable protein, g/d at 26.5 lb DMI	1,085
NE <sub>L</sub> , Mcal/lb DM <sup>a</sup>	0.62
NE <sub>L</sub> , Mcal/lb DM <sup>b</sup>	0.55
NE <sub>L</sub> , Mcal/lb DM <sup>c</sup>	0.67

<sup>a</sup> Calculated for the total diet using the NRC 2001 model and analyzed chemical composition for corn silage, wheat straw, alfalfa hay, and concentrate mixture.

<sup>b</sup> Calculated using NE<sub>L</sub> values assigned by Dairy One Laboratory for individual ingredients, using the Van Soest variable discount factors and correct at intake of 3× maintenance.

<sup>c</sup> Calculated using NE<sub>L</sub> values provided by Dairy One Laboratory using NRC 2001 equations (Ohio State summative equation) for individual ingredients, at intake appropriate for dry cows.

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.

## NE<sub>L</sub> values are tricky

The NE<sub>L</sub> value specified for the same diet may vary considerably depending on method used to derive the value. While we have used NE<sub>L</sub> widely to formulate and evaluate high-straw low-energy diets, nutritionists, veterinarians, and producers have expressed confusion on how to arrive at the “correct” NE<sub>L</sub> content of the rations. Because of the confusion, it may be better to focus on providing the recommended intakes of forage NDF (10 - 12 lb/day) as a primary guideline for achieving the correct energy density.

In calculating NE<sub>L</sub> values, some of the difficulty stems from the changeover to use of the NRC 2001 equations and calculation methods, and some is related to differences in how feed analysis laboratories calculate and report NE<sub>L</sub> values. It is important that those working to formulate and monitor the rations are using consistent units for evaluating NE<sub>L</sub> density of the diets to avoid confusion.

An example of the potential confusion in using NE<sub>L</sub> values for high-straw low-energy rations is shown in Table 1. The diet was fed to one group of cows and heifers in our most recently completed experiment (Janovick Guretzky et al., 2006). Feed ingredients were sampled weekly, formed into monthly composites, and analyzed by Dairy One Laboratory (Ithaca, NY) using wet chemistry techniques. Using the actual measured cow variables and analyzed feed composition, we compared the NE<sub>L</sub> density of the ration calculated three different ways. The value for the total diet calculated by the NRC model was 0.62 Mcal/lb DM. If we used the NE<sub>L</sub> values from Dairy One for individual ingredients to calculate the total dietary NE<sub>L</sub> density, the value was 0.55 Mcal/lb DM. However, if we used the values for individual ingredients provided by Dairy One as “NRC values” for dry cows, the total diet NE<sub>L</sub> was 0.67 Mcal/lb DM! Why the large discrepancy?

The NE<sub>L</sub> value is technically correct only for the feed that a cow actually eats. This is because ingredients in a diet influence the rumen digestibility of other ingredients, some positively and some negatively. A classic example of this phenomenon is that high concentrate addition to a diet decreases the digestibility of the NDF components in forages by changing the rumen environment. Consequently, the NE<sub>L</sub> density of a diet cannot be determined accurately by adding together the calculated NE<sub>L</sub> values of individual ingredients. The NE<sub>L</sub> value of an individual feed ingredient is only correct if it is fed as the only feed ingredient to a cow, which of course is not very common!

In addition, the digestibility of the dietary DM decreases as total feed intake increases. This decrease is more pronounced for the NDF fraction than for starch, and is greater for grass-type forages than legumes. The NRC incorporates a standard reduction of 4 percentage units digestibility for each multiple of maintenance intake. Because different components of the diet are affected differently by the intake effect, Van Soest (Cornell University) devised a variable discount system. These are used by Dairy One, for example, to report an NE<sub>L</sub> value at 3× maintenance, which would be equivalent to the intake need to produce about 66 lb of milk (see [www.dairyone.com/Forage/FactSheet/NRC\\_201\\_Energy\\_Values.htm](http://www.dairyone.com/Forage/FactSheet/NRC_201_Energy_Values.htm). and

[www.dairyone.com/Forage/Newsletters/199903.pdf](http://www.dairyone.com/Forage/Newsletters/199903.pdf)). Because the  $NE_L$  value of straw is severely penalized by the Van Soest variable discount system, the calculated value of the diet is considerably lower than the NRC model value for the total ration (Table 1). On the other hand, using the laboratory values assigned to individual ingredients by the laboratory using NRC principles and then reconstructing an “average” value of the ration overestimates the  $NE_L$  density.

The bottom line is that those working with formulating and monitoring diets must be consistent in which energy and laboratory units are being applied, and realize that taking the assigned values from analytical results may not be appropriate for dry cows fed mixed diets. Values calculated for the total diets by using the NRC 2001 or CNCPS/CPM models will always be more accurate predictors.

### **Secrets for success**

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. In situations where “train-wrecks” have been reported, it is almost always the case that one or more of these factors has been faulty, not the 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. 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. If cows sort the straw, this means that some cows will be consuming a higher energy diet than formulated, and some (the more timid cows) will be left with a much lower quality ration than desired. 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. 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”.

Another common pitfall is 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. Bunk space must be adequate and feed pushed up frequently. If feed is not pushed up, cows will not be able to consume what they need.



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 producers may experience a rash of calving-related health problems until the situation is corrected.

While the nutritional concepts of these rations are simple, the approach and implementation are not problem-free. Attention to detail is a must. The system is not “easy” or a lazy approach to dry cow care. When implemented correctly, results are good. High-straw low-energy diets are not remedies for poor feeding management or bad facilities.

### **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 is important for prevention of DA. We feel that the control of energy intake is a critically important factor in maintaining a steady energy intake and in preventing other disorders around calving such as ketosis and fatty liver.

In this context, then, whether other low-energy ingredients will produce the same desirable results remains uncertain. Many producers and nutritionists have used low-energy ingredients such as poor-quality hay, oat hulls, cottonseed hulls, corn stalks, soybean residue, and flax shives with varying reports of success. To our knowledge, there is no controlled research comparing any of these alternate sources with straw or other dry cow nutrition strategies. With the roughage type materials, the key consideration is uniform processing so that cows do not sort and the formulated profile of nutrients is actually consumed. In the case of the concentrate-type or finely ground ingredients, energy content is low but particle size is so small that rate of passage is too fast, allowing particles to escape more quickly even though they are not digested. In this case, dry matter intake by the cows may increase so that total energy intake still exceeds requirements by a considerable factor.

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 or have fermented poorly should not be fed to dry cows, especially the close-ups.

Extensive comparisons of high-straw low-energy diets with conventional diets in cows of widely differing body condition scores are not available. In the field, the diets seem to work well in both thin and fat cows. In fact, many producers have concluded that these

diets are the best way to manage obese cows through calving to minimize the usual problems expected with fat cows.

### **Conclusions and take-home messages**

High-straw low-energy rations are exciting for their potential to markedly improve health during the transition period. The key concept is that we are striving to meet the requirements of the cows for energy and all other nutrients, but not to allow cows to exceed their requirements of energy by large amounts for the duration of the dry period. Provided that these high-straw low-energy rations are formulated, mixed, and delivered properly, results have been positive. Research and field observations indicate that the rations result in better energy balance after calving, with subsequent improvements in health. Milk production is maintained, and field observations suggest that reproductive success may be improved also, although data are lacking.

### **References**

Agenäs, S., E. Burstedt, and K. Holtenius. 2003. Effects of feeding intensity during the dry period. 1. Feed intake, bodyweight, and milk production. *J. Dairy Sci.* 86:870-882.

Dann, H. M., N. B. Litherland, J. P. Underwood, M. Bionaz, A. D'Angelo, J. W. McFadden, and J. K. Drackley. 2006. Diets during far-off and close-up dry periods affect periparturient metabolism and lactation in multiparous cows. *J. Dairy Sci.* 89:3563-3577.

Dann, H. M., D. E. Morin, M. R. Murphy, G. A. Bollero, and J. K. Drackley. 2005. Prepartum intake, postpartum induction of ketosis, and periparturient disorders affect the metabolic status of dairy cows. *J. Dairy Sci.* 88:3249-3264.

Douglas, G. N., T. R. Overton, H. G. Bateman, II, H. M. Dann, and J. K. Drackley. 2006. Prepartal plane of nutrition, regardless of dietary energy source, affects periparturient metabolism and dry matter intake in Holstein cows. *J. Dairy Sci.* 89:2141-2157.

Drackley, J. K. 1999. Biology of dairy cows during the transition period: the final frontier? *J. Dairy Sci.* 82:2259-2273.

Drackley, J. K., H. M. Dann, G. N. Douglas, N. A. Janovick Guretzky, N. B. Litherland, J. P. Underwood, and J. J. Loores. 2005. Physiological and pathological adaptations in dairy cows that may increase susceptibility to periparturient diseases and disorders. *Ital. J. Anim. Sci.* 4:323-344.

Drackley, J. K., T. R. Overton, and G. N. Douglas. 2001. Adaptations of glucose and long-chain fatty acid metabolism in liver of dairy cows during the periparturient period. *J. Dairy Sci.* 84(E. Suppl.):E100-E112.

Grum, D. E., J. K. Drackley, R. S. Younker, D. W. LaCount, and J. J. Veenhuizen. 1996. Nutrition during the dry period and hepatic lipid metabolism of periparturient dairy cows. *J. Dairy Sci.* 79:1850-1864.

Grummer, R.R., D.G. Mashek, and A. Hayirli. 2004. Dry matter intake and energy balance in the transition period. *Vet. Clin. Food Anim.* 20:447-470.

Holcomb, C. S., H. H. Van Horn, H. H. Head, M. B. Hall, and C. J. Wilcox. 2001. Effects of prepartum dry matter intake and forage percentage on postpartum performance of lactating dairy cows. *J. Dairy Sci.* 84:2051-2058.

Janovick Guretzky, N. A., N. B. Litherland, K. M. Moyes, and J. K. Drackley. 2006. Prepartum energy intake effects on health and lactational performance in primiparous and multiparous Holstein cows. *J. Dairy Sci.* 89(Suppl. 1). (Abstr.)

Kunz, P. L., J. W. Blum, I. C. Hart, J. Bickel, and J. Landis. 1985. Effects of different energy intakes before and after calving on food intake, performance and blood hormones and metabolites in dairy cows. *Anim. Prod.* 40:219-231.

Litherland, N. B., H. M. Dann, A. S. Hansen, and J. K. Drackley. 2003. Prepartum nutrient intake alters metabolism by liver slices from periparturient dairy cows. *J. Dairy Sci.* 86(Suppl. 1):105-106. (Abstr.)

Loor, J. J., H. M. Dann, R. E. Everts, R. Oliveira, C. A. Green, N. A. Janovick-Guretzky, S. L. Rodriguez-Zas, H. A. Lewin, and J. K. Drackley. 2005. Temporal gene expression profiling of liver from periparturient dairy cows reveals complex adaptive mechanisms in hepatic function. *Physiol. Genomics* 23:217-226.

Loor, J. J., H. M. Dann, N. A. Janovick Guretzky, R. E. Everts, R. Oliveira, C. A. Green, N. B. Litherland, S. L. Rodriguez-Zas, H. A. Lewin, and J. K. Drackley. 2006. Plane of nutrition pre-partum alters hepatic gene expression and function in dairy cows as assessed by longitudinal transcript and metabolic profiling. *Physiol. Genomics* 27:29-41.

National Research Council. 2001. *Nutrient Requirements of Dairy Cattle*. Seventh rev. ed. National Academy Press, Washington, D.C.

Rukkwamsuk, T., T. Wensing, T., and M. J. Geelen. 1998. Effect of overfeeding during the dry period on regulation of adipose tissue metabolism in dairy cows during the periparturient period. *J. Dairy Sci.* 81:2904-2911.

[www.dairyone.com/Forage/FactSheet/NRC\\_201\\_Energy\\_Values.htm](http://www.dairyone.com/Forage/FactSheet/NRC_201_Energy_Values.htm). Accessed 12/1/06.

[www.dairyone.com/Forage/Newsletters/199903.pdf](http://www.dairyone.com/Forage/Newsletters/199903.pdf). Accessed 12/1/06.