Protein and Energy Needs of the Transition Cow

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Take Home Messages

- Dry matter intake may be decreased 10 to 30% during the period three weeks prior to calving.
- The last 3 weeks prior to calving it is recommended that energy density should be in the range of 1.5 to 1.6 Mcal NE_l/kg DM, CP in the range of 13-14%, NFC between 33 to 38% and NDF >32%.
- More information is needed regarding the metabolizable protein and energy needs of the fetus, placenta, fetal fluids, uterus and mammary gland during the dry period.
- Proper formulation of rations for protein, energy density, fiber and nonforage fiber carbohydrates will help to increase intake prior to calving. Management of body condition, and cow comfort are also critical to assure an excellent transition program.

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, and is currently recognized as the most critical phase of the lactation cycle. 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 that reduce their dry matter intake more than 15% prior to calving, have inconsistent feed intakes after calving, and have metabolic diseases during the transition from dry period to early 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 4.5 to 9 kg of peak milk, which translates into economic losses up to $600 for that lactation. Maximizing prepartum and postpartum dry matter intake is an important key to successful transition cow management. This paper will examine the protein and carbohydrate needs of the transition cow.

■ Metabolic Changes that Occur During the Transition Period

It is helpful to understand the metabolic events that occur during the transition period in order to implement nutritional management recommendations (Drackley, 1997; Goff and Horst, 1997). Concentrations of progesterone in blood decrease and those of estrogen increase as parturition nears (Grummer, 1995). The high circulating estrogen is believed to be one major factor that contributes to decreased DMI around calving (Grummer, 1993). During the last weeks of pregnancy, nutrient demands by the fetus and placenta are the greatest of any point during gestation (Bell, 1995). However, DMI may be decreased 10 to 30% during the period three weeks prior to calving. After calving, the initiation of milk synthesis and rapidly increasing milk production greatly increases demand for glucose for milk lactose synthesis, at a time when feed intake has not reached its maximum. Dairy cows rely almost exclusively on gluconeogenesis (synthesis of glucose) from propionate in the liver to meet their glucose requirements. Limited feed intake during the prepartum and early postpartal period will result in a reduced supply of propionate for glucose synthesis. Amino acids from the diet or from breakdown of skeletal muscle as well as glycerol from mobilized body fat contribute some carbon for glucose synthesis. Supplying adequate glucose for milk synthesis at the time of calving is a tremendous metabolic challenge to cows during the transition period (Drackley, 1993).

■ Nutrient Requirements for Pregnancy

Dry cows require nutrients for maintenance, growth of the conceptus, and perhaps growth of the dam. Estimation of the nutrient requirements for pregnancy by the factorial method requires knowledge of the rates of nutrient accretion in conceptus tissues (fetus, placenta, fetal fluids, and uterus) and the efficiency in which dietary nutrients are utilized for conceptus growth. There are limited data for dairy cattle. In the mature cow carrying a single fetus, maintenance accounts for at least 60% of the total requirement for energy and most specific nutrients. Conceptus growth may account for about 25% of the total energy requirement (Van Saun and Sniffen, 1992; NRC, 1989). Requirements for mammogenesis and prepartum lactogenesis are relatively small in multiparous cows, but in first calf heifers are more significant (Jakobsen, 1956). Requirements for maternal tissue reserves for mature cows should be small as replenishment of body fat and labile protein lost in early lactation should be almost complete by dry-off (Bell, 1995).

Efficiency of utilization of metabolizable energy for conceptus growth based on several studies is low at approximately 13% (Bell, 1986). There is a very high-energy cost of metabolism in the placenta, a tissue that grows little but is highly active during late pregnancy. If the factor of 13% is applied the derived value of 5 Mcal/d for a 700 kg cow delivering a 45 kg calf is almost identical to that proposed by NRC (1989). Moe and Tyrrell (1972) using calorimetry data observed that the efficiency of energy capture by the gravid uterus might decrease as pregnancy advances. In addition, previous estimates did not include energy requirements if tissue gain by the mammary gland incurred an energy cost. Vandehaar et al (1999) calculated that prepartum mammary gland development might require an additional 3 Mcal NE_L/d increasing NRC (1989) requirements for metabolizable energy to as high as 9 Mcal/d.

▪ Protein Needs of the Dry Cow

The potential for modulation of yield by maternal protein reserves is likely to be diminished in cattle compared to monogastrics and result in lactation diets to be formulated at higher metabolizable protein levels relative to requirement than diets for monogastric animals. Higher dietary protein levels are fed in dairy cattle diets for several reasons. Values for metabolizable protein supply are uncertain, there is inadequate data for microbial yield, and estimates of the amount of ruminal undegraded protein (RUP) delivered to the intestine are also not adequately known. Higher protein diets create less likelihood that early lactation dietary protein deficiencies will need to be compensated for by mobilization of reserve tissues. Currently, there is interest in reducing excess dietary protein in diets for lactating cows because of environmental, reproductive, and economic concerns. The NRC (1989) recommendation for crude protein (CP) in the diets of dry and pregnant cows is 12% of dietary DM; no recommendation for rumen undegradable protein is provided. Although poorly understood, an increase in protein supply in the diets of late gestation dry cows has been shown to improve milk production and milk protein yield (Moorby et al, 1996), milk protein content, and reproductive efficiency (Van Saun et al, 1993). However, other work (Sharma et al, 1995; Van Saun, 1993; VandeHaar et al, 1995; Wu et al, 1997; Putnam et al, 1998, 1999; Donkin et al, 1998) has failed to show a relationship between prepartum protein supply and postpartum performance of dairy cows.

Increasing dietary CP beyond 12% during the dry period by addition of feeds that are high in undegradable protein reduced the incidence of ketosis in multiparous cows (Van Saun et al, 1995). Increasing undegradable protein from 2.8 to 6.7 or 10.5% of DM did not alter DMI, yields of milk, protein or fat (Huyler et al, 1999). Increasing total protein, undegradable protein, or both during the transition period has resulted in reduced feed intake (Van Saun, 1993; Crawley and Kilmer, 1995; Donkin et al, 1998). Increased protein intake during gestation above that recommended by NRC (1989) has been associated with lower incidences of ketosis and retained placenta (Curtis et al, 1985). Infusion of lysine and methionine has been shown to increase very low-density lipoprotein synthesis in the liver (Durand et al, 1992), which may help prevent fatty liver syndrome.

Requirements for CP during the transition period should be met when feeding cows diets containing 12% CP at predicted dry matter intakes. When looking at individual points for 65 cows from the study of Dann et al (1999) the last 10 days prior to calving, there is a considerable variation among individual cows in daily protein intake (Figure 1). If mean DMI is 14 kg/d and mean CP is 11% then at -1 Standard Deviation of the mean for DMI would be 10.8 kg/d and 14.4 % CP. Putnam et al (1998) demonstrated that cows fed 10.6, 12.7 and 14.5 % CP were all in positive nitrogen balance during the last three weeks prior to calving (Figure 2). Although some positive results have been noted when increasing CP beyond 12% by feeding additional undegradable protein, the results have been inconsistent and sometimes, negative effects on DMI have been observed. In a recent study, we evaluated prepartum diets containing 13.3 vs 17.8% CP in the diet DM (Putnam et al, 1999). Cows provided the 17.8% CP diet had lower DMI per unit of BW following parturition, and higher NEFA concentrations for 4 weeks after calving compared to those cows fed 13.3% CP prepartum.

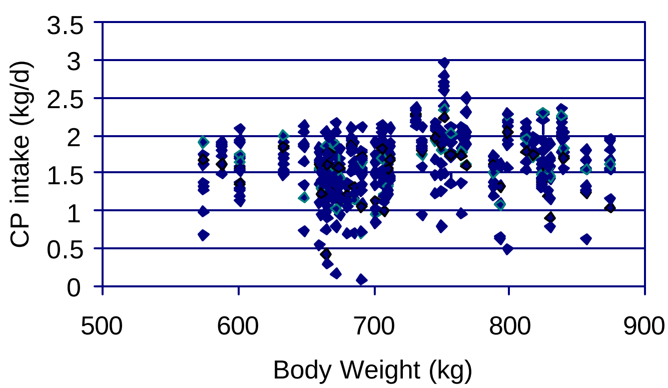

Figure 1. Crude protein intake for last 10 days prior to parturition.

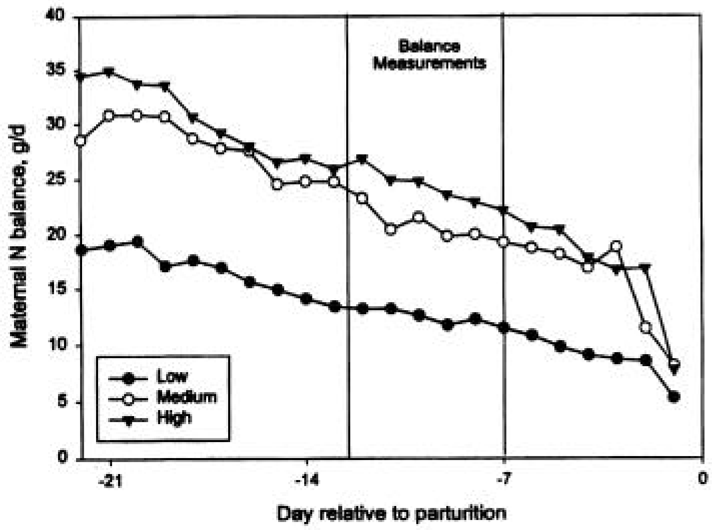

Figure 2. Predicted maternal N balance from 28 to 1 d prepartum of cows fed low, medium, or high CP diets.

Differences in total yield of absorbed protein from CP can vary, thus confounding estimations of dietary CP adequacy. Putnam and Varga (1998) reported differences in true efficiency (60.6% vs. 55.3%) of dietary nitrogen between low (10.6% CP) and moderate (12.7% CP) dry cow diets, and reported that plasma urea nitrogen (PUN) increased from 12.0 mg/dl to 14.6 mg/dl as dietary CP increased between these two treatments. This increase in PUN level, while it may reflect differences in efficiency of utilization for absorbed protein, may also represent differences in microbial capture of ruminally available N, therefore differences in microbial protein yield may have impacted the supply of absorbed protein. Although these two levels of CP intake did not result in differences in performance, applying data reported in the paper to the Cornell Net Carbohydrate and Protein System Model (Fox et al, 1990) yielded estimates of metabolizable protein (MP) supply. These estimates suggest that there was little difference in absorbed protein supplied to the dam despite the differences in CP intake. If the maternal tissues do not see differences in metabolizable protein, there is little reason to expect differences in performance as a function of CP supply.

Progress towards establishing the protein and amino acid requirements of the late gestation dairy cow continues to be made. Production responses to ruminally protected amino acids to improve the content of lysine and methionine in metabolizable protein show consistent improvements of content and yield of milk protein, but only when lysine:methionine is adequate and is approximately 3:1 (Sloan et al, 1998). The magnitude of responses to improving lysine and methionine in metabolizable protein may be dependent on their adequacy in metabolizable protein during late gestation (Carson et al, 1998. In a review by Garthwaite et al (1999), prepartum supplementation of rumen protected methionine and lysine in five trials resulted in responses (compared to the control within trial) of +0.5 kg dry matter intake, +1.7 kg milk, + 0.06% units milk protein, +0.79 g milk protein and + 85 g milk fat. Two additional experiments observed negative responses to protected amino acids primarily because excess methionine relative to lysine was fed.

▪ Dietary Energy to Protein Relationships

Strategies that have been able to increase plasma glucose concentrations in late gestation have resulted in reduced concentrations of plasma NEFA, BHBA, and liver fat and triglycerides (Studer et al, 1993). Based on previous research in our laboratory (Putnam and Varga, 1998), increasing the supply of protein during late gestation may increase glucose concentrations by providing glucogenic precursors. Glucose concentrations were highest for cows provided the 14.5% CP diet (**Table 1**) however this did not result in any effects on milk yield or component yields. We further investigated the use of higher levels of protein in the diet and found no effect on glucose concentration in blood (13.3 vs 17.8% CP in diet DM). Both the 12.7% CP diet in the previous study and the 13.3% CP diet in the latter study provided similar amounts of protein (1422 vs. 1370 g/d), while intakes of CP for the 14.5% CP diet in the previous study, and the 17.8% CP diet in this study, were 1639 and 1878 g/d, respectively. Caloric intake was similar across treatments in both studies, this created a range in energy: CP ratios (Mcal: kg CP). While the groups consuming approximately 1400 g/d of CP had energy to CP ratios approximating 12:1, the diets providing 1639 g/d CP had a ratio of 10.6:1 and the group consuming 1878 g/d CP (17.8%CP) had a ratio of 8.8:1. The glucose responses to dietary protein supplementation in late gestation may be limited, in part, by the availability of energy relative to the energetic costs associated with nitrogen excretion.

Table 1. Mean concentrations of selected metabolites in blood during the prepartum period.

Item	%CP in diet DM			
	10.6	**12.7**	**14.5**	**P < F**
Glucose, mg/dl	59.2	63.0	64.9	0.10
BHBA, mg/dl	23.2	22.7	21.1	0.17
NEFA, meq/L	225.7	217.2	205.9	NS
	Cows with BCS > 3.25 only			
Glucose, mg/dl	59.0	63.3	66.0	0.05
BHBA, mg/dl	24.2	24.4	21.2	0.14
NEFA, meq/L	276.2	229.4	187.6	0.05

Vanderhaar et al (1999) conducted a study to determine if increased nutrient density in prepartum diets improves nutrient balance in peripartum cows. Four diets ranged from 1.30 to 1.61 Mcal NE_L/ kg and 12.2 to 16.2% CP. Energy to protein ratios ranged from 8.6:1 to 10:1. When evaluated using the CNCPS model (Fox et al, 1990) only the low-protein low-energy treatment was negative in metabolizable protein needs. In addition, the low energy to protein ratio more than likely forced some animals to inefficiently utilize protein as an energy source confounding the effects of the treatments in terms of energy needs of the prepartum cows in that study.

▪ Energy Needs of the Transition Cow

Carbohydrate metabolism in the early postparturient cow is dominated by the massive requirement for glucose, mostly for lactose synthesis. The challenge posed for liver and other nonmammary tissues comes sharply into focus when the estimated glucose uptake of ~1,800 g/d at day 4 of lactation is compared with the estimated supply of dietary glucose precursors (propionate and amino acids). Even assuming that all of the absorbed propionate and amino acids (minus requirement for milk protein) are available for glucose synthesis, these substrates could account for at most, about 1,200 g/d of glucose equivalents, equivalent to no more than two thirds of the mammary glucose requirement, to which must be added the mandatory glucose requirements of other tissues, such as the brain (Bell, 1995). Glycerol and lactate will make up part of the shortfall in glucose precursors.

Energy intake is determined by the amount of dry matter consumed and the energy density of the diet dry matter. The NRC (1989) recommendations for energy density of diets fed to dry cows is 1.26 Mcal NE_L/kg. Dry matter intake can decrease as much as 30% three weeks prior to calving; intake may be as high as 15 kg/d at three weeks before calving to approximately 10 kg/d the week to last few days before calving. Therefore a constant recommendation of 1.26 Mcal NE_L/kg of diet DM would not be adequate especially the last week prior to calving for most mature cows. Grummer (1998) demonstrated that to meet the energy needs for first calf heifers energy density of the diet would have to be increased almost 30% over current NRC (1989) recommendations. In order to acclimate cows to the lactation diet and to adequately meet the needs of all groups of animals, higher density rations need to be fed.

Diets that are easily degraded by the ruminal microorganisms generally result in the production of more propionic acid. Approximately, 80% of propionic acid that is presented to the liver is metabolized to glucose. In order for high rates of gluconeogenesis to be maintained prepartum, highly fermentable carbohydrate sources need to be fed. This may protect the cow from fatty acid infiltration of the liver as well as ketosis in the first few weeks postpartum. In addition, feeding diets prepartum that are higher in nutrient density may enhance feed intake. Feeding diets higher in fermentable carbohydrates during the prepartum period may acclimate the microbial population to the postpartum diet, promote ruminal papillae development, increase absorptive capacity of the rumen epithelium and reduce lipolysis by increasing glucogenic precursors. Dirksen et al (1985) demonstrated that a decrease in fiber in the prepartum diet promoted development of the ruminal papillae and increased the capacity for VFA absorption. These researchers speculated that development of papillae was essential to minimize VFA accumulation, to minimize a decline in pH, and reduce the occurrence of acidosis when fresh cows were fed high grain diets postpartum. Dann et al (1999) showed that cows fed steam flaked corn vs dry cracked corn had reduced NEFA prepartum (Table 2) and improved DMI prepartum (Table 3). The main effects of postpartum health and production were not affected by prepartum rations, however milk yield was higher for cows fed steam flaked corn diet from six to thirteen weeks into lactation.

Table 2. Prepartum blood metabolites and hormone concentrations of cows fed cracked corn (CC) or steam-flaked corn (SFC) during the prepartum period (Dann et al, 1999).

	Prepartum				
Item	**CC**		**SFC**		**P**
n	33		32		
	_	SEM		SEM	
Glucose, mg/dl	66.8	0.81	68.2	0.82	0.22
BUN, mg/dl	9.74	0.33	8.81	0.33	0.05
NEFA, µeq/L	251	37.1	145	37.5	0.05
Insulin, ng/ml	0.51	0.05	0.58	0.05	0.29

Table 3. Prepartum DMI, BW, and body condition score (BCS) of cows fed cracked corn (CC) or steamed flaked corn (SFC) during the prepartum period (Dann et al., 1999).

Item	Prepartum				P
	CC		SFC		
n	33		32		
	_	SEM	_	SEM	
DMI, kg/d	13.6	0.44	14.6	0.45	0.12
BW, kg	754	13.7	759	14.0	0.79
BCS Change	0.02	0.04	0.13	0.04	0.05

The effect of diets high in fermentable fiber vs rapidly fermentable starch still need to be evaluated as transitional rations for dairy cows. Though highly fermentable starch sources increase glucogenic precursors for the transition cow in certain situations, type of concentrates and length of feeding prepartum may increase body condition and predispose cows to fatty liver infiltration and other metabolic diseases. In a recently completed pilot study we demonstrated that cows provided corn silage based rations with a portion of the fiber coming from nonforage fiber sources (NFFS) had higher dry matter intakes prepartum in comparison to conventionally fed dry cows. These diets were based on corn silage as the primary forage source (40% of ration DM), approximately 20% of the ration DM coming from NFFS such as cottonseed hulls, soyhulls, and corn cobs, with the remainder from soybean meal, molasses, corn, distillers, vitamins and minerals. Preliminary data (Table 4) from this study showed approximately a 3 kg increase in DMI compared to the last five prepartum studies we have conducted feeding conventional dry cow rations (~65% 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 18 kg of DMI the first two weeks of lactation with minimal health problems. More research is needed to evaluate the fermentability and type of carbohydrates required by cows during transition, but also the particle length of forage that is fed.

Table 4. Dry matter intake prepartum of a ration containing nonforage fiber sources (NFFS) and a conventional dry cow ration.

Weeks	-4	-3	-2	-1		Mean
NFFS DMI, kg/d	17.7	17.7	16.1	13.9		16.3
65% forage based ration DMI, kg/d	15.0	14.2	13.0	11.5		13.5

Specific recommendations for NFC in the ration are not available in the current NRC for transition cow diets. In order to achieve a high energy density at a time when DMI might be decreasing as much as 30% the last three weeks prior to calving, NFC should be in the range of 33 to 38% in diet DM. Energy density should be in the range of 1.5 to 1.55 Mcal NE_L/kg DM, CP in the range of 13-14% and NDF >32%. The NFC recommendation is similar to diets fed to early lactation cows, however more fiber can be included due to lower levels of CP in the transition diet. Diets with elevated energy density should not be fed for more than three weeks prior to calving if cows have adequate condition (>3.5 on a 5.0 scale). . When looking at individual points for 65 cows from the study of Dann et al (1999) the last 10 days prior to calving, there is a considerable variation among individual cows in daily energy intake (**Figure 3**). For example, for a 700 kg dry cow the protein needs according to NRC (1989) is 15 Mcal NE_L.

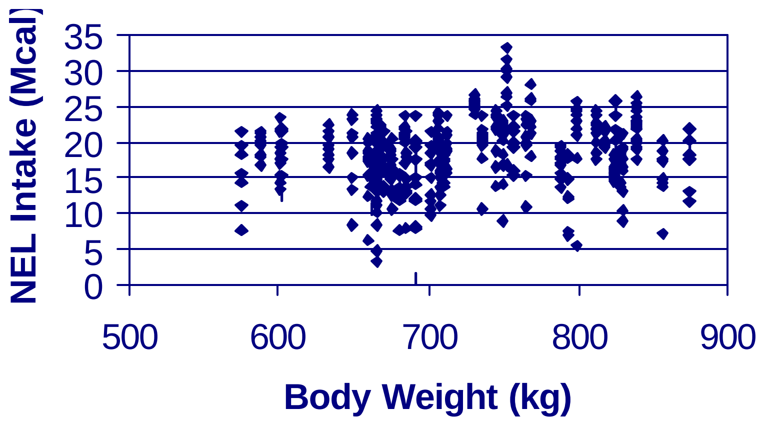

Figure 3. NE_L intake last 10 days prior to parturition.

■ Summary

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 dry matter intake 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 excellent quality forages will assure an excellent transition program for the high producing dairy cow.

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