Protein and Energy Nutrition of the Transition Cow

Lorraine Doepel[1], John J. Kennelly[1] and Hélène Lapierre[2]

[1]Dairy Research & Technology Centre, Dept. of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, AB, Canada T6G 2P5
E-mail: ldoepel@afns.ualberta.ca
E-mail: john.kennelly@ualberta.ca
[2] Agriculture and Agri-Food Canada Research and Development Centre, 2000 Route 108 East, Box 90 Lennoxville QC J1M 1Z3

Take Home Messages

- introduce grain into the dry cow diet at least 3 weeks before expected calving to adapt the rumen microbes and papillae to a high starch diet and to help maintain adequate energy intake
- avoid overconditioning at calving as overconditioned cows eat less and are more likely to develop metabolic disorders than properly conditioned cows
- transition cow diets containing 1.6 Mcal/kg net energy and 16% crude protein may be warranted

Introduction

The transition period for the dairy cow refers to the three weeks before calving to the three weeks after calving. During this time, the cow experiences many physiological changes in preparation for calving and the upcoming lactation. Associated with these changes is a depression in feed intake. The reduction in intake and the substantial increase in nutrient requirements for fetal growth and mammary gland development may contribute to an increased incidence of metabolic disorders. Most metabolic diseases of dairy cows occur within the first two weeks of lactation (Goff and Horst, 1997). Prevention of periparturient disorders is of utmost importance because the occurrence of one disorder predisposes the animal to other metabolic problems. For example, Curtis et al. (1985) found that cows with left displaced abomasum had an increased risk of developing metritis and ketosis. In addition to a greater incidence of metabolic disorders, other signs of a poor transition period include excessive body condition loss after calving and cyclic feed intakes. A high level of management is therefore central to a smooth transition and will help ensure optimal productivity in the subsequent lactation.

Metabolic status of the transition cow

The late pregnancy period is one of metabolic transition. Although this transition is associated with parturition, it does not occur abruptly but gradually over a 2 to 4 week period prepartum. The transition involves alterations in adipose tissue, liver, and skeletal muscle metabolism and several hormonal changes that are involved in initiation of parturition and initiation and maintenance of milk production.

As parturition approaches, plasma growth hormone concentration increases and plasma insulin concentration decreases. Plasma estrogen increases during late gestation with a rapid increase just before calving and then decreases at calving. The importance of estrogen in relation to fat mobilization will be discussed later. Progesterone concentrations remain elevated until about day 250 of gestation and then decrease until calving (Grummer, 1995).

In the prepartum period, energy requirements exceed dietary energy supply due to increased demands of the growing fetus and a decline in feed intake. This leads to adipose tissue mobilization, mediated by enhanced lipolysis (fat breakdown) and reduced lipogenesis (fat synthesis). A reduction in lipogenesis occurs as early as 15 days prepartum. Lipolysis results in the release of non-esterified fatty acids (NEFA) into the bloodstream. The NEFA can then be taken up by organs such as the mammary gland or liver and be incorporated into milk fat or used as an energy source. When the NEFA are extracted by the liver they can be oxidized to completion, partially oxidized to ketone bodies or esterified to form triglycerides (TG). The ruminant liver has a limited capacity to remove TG, therefore, if the cow mobilizes a lot of body fat, the TG accumulate in the liver leading to the condition of fatty liver. Fatty liver appears to be a predisposing factor for the development of ketosis.

Hormonal changes associated with parturition may be involved with the increase in liver TG concentrations in the periparturient period. As stated earlier, plasma estrogen of placental origin increases as parturition nears. The peak in estrogen may promote fatty acid mobilization from adipose tissue during late pregnancy independent of any change in feed intake and energy balance. In cows with elevated NEFA concentrations, such as those approaching parturition, estrogen administration increases TG accumulation in the liver (Grummer et al., 1990). In nonruminants, estrogen increases liver fatty acid esterification (Weinstein et al., 1977). Esterification is further enhanced by low progesterone levels. The drop in progesterone that ruminants experience at calving may therefore have an influence on fatty liver development.

▪ The Importance of Maximizing Feed Intake

Gradual reductions in dry matter intake (DMI) begin at 3 weeks prepartum and accelerate during the final 7 days before calving. Bertics et al. (1992) reported a 28% drop in intake in control cows compared to cows force-fed through rumen cannulae for the final 17 days before calving. Data from 65 cows at the University of Alberta dairy herd demonstrate that DMI drops 30% between day 20 and day 1 before calving (Figure 1) (unpublished results). Maximizing feed intake is crucial to avoiding negative energy balance in the periparturient period. Feed intake depression, and thus negative energy balance, in large part determines the extent of hepatic TG accumulation by day 1 postpartum. Liver TG of cows that were force-fed prior to calving increased 75% between day 17 before calving and day 1 after calving, whereas they increased 227% in cows that were allowed to experience feed intake depression (Bertics et al., 1992).

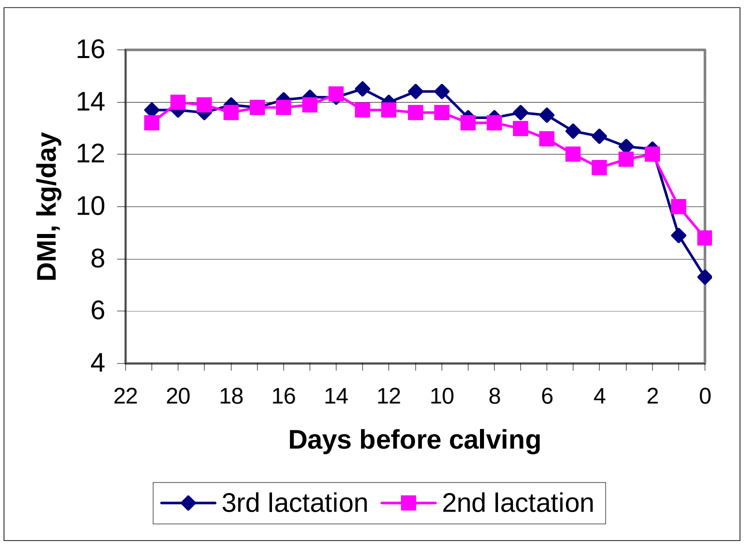

Figure 1: Dry matter intake of 2nd and 3rd lactation cows from the University of Alberta dairy herd.

Maximizing feed intake increases the supply of energy and glucose from acetate and propionate, and the supply of amino acids, which can be used for milk protein synthesis. Large amounts of these nutrients derived from the diet will reduce the cow's reliance on body stores to support milk production resulting in smaller losses of body condition. Maximizing feed intake is also an important factor in reducing the incidence of metabolic diseases in the early postpartum period.

Multiple factors are involved in feed intake reduction. Feed intake depression may be higher for cows consuming high grain diets compared to those on high forage diets. Coppock (1972) fed 4 diets ranging from 75% to 30% forage and found that the percentage decrease in feed intake in the immediate prepartum period was greatest for cows consuming the low forage diets.

Body condition of the cows may also play a role in feed intake. Emery (1993) examined the feed intake of 20 cows in the dry period. Cows with body condition score >3.6 consumed dry matter at 1.5% of body weight while cows with body condition score # 3.6 consumed dry matter at 2% of body weight. The overconditioned cows also had a higher incidence of health disorders postpartum. Garnsworthy and Jones (1987) also reported that overconditioned cows had poor appetites postpartum. Fronk et al. (1980) fed cows to either maintain or gain body condition during the dry period. After parturition, the overconditioned cows mobilized more body fat, as indicated by higher levels of NEFA, and had a higher incidence of postpartum metabolic disorders, particularly milk fever, ketosis, and mastitis.

▪ Increasing the Energy Density of the Diet.

Carbohydrate

Energy Intake The current NRC gives only one set of nutrient recommendations for the entire dry period. For the close-up dry cow, these recommendations may not be adequate for two reasons. Firstly, the growing fetus has greatly increased nutritional demands during this period. Moe and Tyrrell (1972) demonstrated that the cow's energy requirement increases 23% during the last month prepartum. Secondly, as already discussed, DMI decreases dramatically during the final three weeks before calving. To combat this drop in intake, the energy density of the diet should be increased. Generally, increasing the energy density of the diet for the last 3-4 weeks prepartum increases energy intake because there are no, or only minimal, declines in feed intake. Vandehaar et al. (1999) fed cows 1 of 4 diets for the last 28 days of gestation: 1) 1.3 Mcal/kg NE_L and 12.2% CP (LL); 2) 1.49 Mcal/kg and 14.2% (MM); 3) 1.61 Mcal/kg and 15.9% (HH); and 4) 1.48 Mcal/kg and 16.2% (MH). The cows fed the HH diet consumed 14% more dry matter and 40% more energy than the cows fed the LL diet. As a result, the HH cows gained body condition during the last 3 weeks prepartum while the LL cows lost body condition. In addition, the HH cows tended to have lower NEFA concentrations over the last 2 weeks prepartum compared to the LL cows (176 vs. 233 μM). It is generally reported that there is a positive correlation between plasma NEFA and liver TG levels at calving. In the above mentioned study, the cows fed the HH diet had 40% less liver triglycerides compared to cows fed the

LL diets. Cows with reduced liver TG content should be at reduced risk for the development of fatty liver and ketosis.

While feeding an energy dense diet during the last 3-4 weeks before calving appears beneficial, feeding it for extended periods of time may have no benefits or actually be detrimental. Grum et al. (1996) found that cows fed a high grain diet during the entire dry period did not have reduced liver TG at calving compared to the cows fed a typical low energy dry cow diet even though energy intake was higher. Grummer et al. (1995) reported that heifers fed a diet containing 1.6 Mcal/kg NE_L for 15 weeks before calving consumed less feed but equal energy during the last 10 days prepartum than heifers fed a diet of 1.3 Mcal/kg NE_L.

Using ingredients in the transition cow diet that have higher ruminal carbohydrate availability may also be beneficial in terms of milk production and lipid metabolism. Dann et al. (1999) fed diets that either contained cracked corn (CC) or steam flaked corn (SFC) from 28 days precalving to 63 days postcalving. Plasma NEFA were lower in both the prepartum period and from weeks 2 to 9 postpartum in the cows fed the SFC diet. There was no difference in DMI between the 2 groups but milk production was higher in the cows fed SFC postpartum (45.2 kg vs. 42.9 kg). The milk yield response was probably due to the higher starch availability of the steam flaked corn.

Rumen Adaptation During the dry period, when cows are changed from a low forage to a high forage diet, the rumen environment also changes. In cows fed a high forage diet, the microbial population consists of a low number of lactate producers (starch digesters) and lactate users (convert lactate to acetate and propionate), and a large number of cellulolytic bacteria. One of the results of feeding a low concentrate diet is that the rumen papillae, which are required for the absorption of volatile fatty acids (VFA), are reduced in length. If the fresh cow is abruptly switched from a high forage diet to a high concentrate diet, she may develop rumen acidosis because the lactate producers multiply much more rapidly compared to the lactate users. As a result, lactate accumulates and the pH in the rumen drops dramatically. Because the rumen papillae are not developed, the VFA are poorly absorbed and the rumen pH is further reduced, killing or inactivating many of the rumen protozoa and bacteria. To prevent the development of rumen acidosis, the rumen microbes and papillae must be adapted to a high starch diet before calving. Adaptation of the microbes requires about 3 to 4 weeks, while full development of the papillae requires about 5 weeks. Research is currently being conducted at the University of Alberta to determine the optimum time to introduce grain feeding before calving.

Fat

Although supplemental fat is not recommended in the early postpartum period, it may be beneficial in the dry period. Grum et al. (1996) fed cows 1 of 3 diets during the dry period – a low energy diet (30% concentrate), a high grain, high energy diet (HG, 49% concentrate), and a high fat, high energy diet (HF, 14% concentrate + 6.5% added fat). At one week before expected calving, all cows were fed the same transition diet. Cows fed the high fat diet had lower levels of liver TG at 1 day postpartum (7.3%, 1.4%, and 5.9% for the control, HF, and HG diets, respectively) and lower levels of plasma NEFA than cows fed the other diets. These results are surprising because the cows fed the HF diets had reduced DMI and actually lost body condition during the dry period. With lower nutrient intakes cows would be expected to increase, rather than decrease, fat accumulation in the liver at calving. It's not known whether these same effects would be observed in cows maintaining or gaining body condition during the dry period.

▪ Increasing the Protein Density of the Diet

Feeding late gestation cows diets higher in crude protein (CP) than current NRC recommendations may be beneficial. Curtis et al. (1985) reported a lower incidence of ketosis and retained placenta in cows fed high protein diets prepartum. Moorby et al. (1996) demonstrated that increasing undegraded protein supply to cows in late gestation improved milk production and milk protein yield. Van Saun et al. (1993) fed primiparous cows diets containing either 12.4% or 15.3% CP. The additional protein in the high protein diet was from undegradable sources. Cows consuming the high protein diets had improved body condition postpartum and increased milk protein percentage. The authors speculated that the additional undegradable protein intake was used to meet the fetal and maternal growth requirements in late gestation, thus reducing mobilization of the maternal protein pools. Conversely, Putnam and Varga (1998) found no differences in milk production, milk protein content, or body condition score when cows were fed prepartum diets containing 10.6, 12.7, or 14.5 % CP. In this case, the diets were formulated to be similar in CP degradability. These authors concluded that NRC CP recommendations are adequate for the maintenance of maternal protein balance in late gestation. Of interest in this study was that in cows with a BCS > 3.25, plasma NEFA were lower, and plasma glucose higher, with the high protein diet. This suggests that the additional amino acids supplied by the high protein diet were used by the fetus as an energy source thus sparing glucose and increasing the maternal glucose concentration.

■ Energy and Protein Interaction

Few studies have looked at the interaction of energy and protein intake of the transition cow. We recently conducted a study at the University of Alberta where four different precalving diets were fed. At 21 days before expected calving, multiparous Holstein cows were fed 1 of 4 diets: high energy-high protein (HEHP), high energy-low protein (HELP), low energy-high protein (LEHP), and low energy-low protein (LELP). Diet composition and calculated nutrient levels are shown in Table 1. Milk yield and composition were recorded for the first six weeks of lactation. Liver biopsies were performed before the cows were fed the dietary treatments, and then at day 1 and 21 of lactation. Blood was sampled weekly during the prepartum treatment period and for the first 4 weeks of lactation. After calving, all the cows were fed the same early lactation ration.

Table 1: Composition and calculated nutrient content of prepartum test diets.

	Composition of TMR (DM basis)			
Ingredients:	**HEHP**	**HELP**	**LEHP**	**LELP**
Grass Hay	16.4	12.3	30.6	29.5
Alfalfa Silage	6.7	6.7	6.7	6.7
Barley Silage	35.0	34.4	11.6	12.1
Barley Grain	18.4	27.6	5.7	11.3
Beet Pulp	8.4	8.4	3.3	3.3
Blood Meal	3.3	--	6.0	1.0
Corn Gluten Meal	2.4	.37	2.7	1.0
Soybean Meal	2.4	.37	1.6	1.5
Canola Meal	2.4	.37	1.3	.37
Oat Hulls	--	4.7	28.0	30.5
Tallow	2.1	2.1	--	--
Mineral-Vitamin Mix	2.14	2.14	2.14	2.14
Dical	.07	.15	.15	.22
Limestone	.15	.22	.22	.30
Nutrients:				
NEL (Mcal/kg)	1.61	1.61	1.27	1.27
CP (%)	16.27	11.09	16.33	11.23
UIP (% of CP)	41.66	28.8	48.83	34.03
ADF (%)	25.87	26.45	32.47	33.6
NDF (%)	42.66	44.25	50.10	52.24
Ca (%)	.67	.67	.65	.67
P (%)	.37	.36	.36	.36
Na (%)	.23	.21	.22	.20
K (%)	1.19	1.10	1.12	1.13
Cl (%)	.37	.36	.37	.36
S (%)	.22	.19	.20	.18
DCAB (Meq/kg)	162	152	152	161
Forage:Conc	67:33	67:33	80:20	82:18

HEHP: high energy, high protein; HELP: high energy, low protein
LEHP: low energy, high protein; LELP: low energy, low protein

Dry matter intake during the prepartum period averaged 12.7 kg. Cows fed the LEHP diet ate more than cows fed the HELP diet but intake among the other treatment groups was not different (Table 2). Across treatments, DMI dropped from 13.7 kg at 4 weeks prepartum to 7.5 kg on the day of calving. Most of this drop occurred during the week before calving (Figure 2). Cows fed the LEHP diet experienced the largest drop in intake during that time. Postpartum DMI of the cows fed the HEHP diet was significantly higher than that of the cows fed the low energy diets. Milk yield was not significantly different among the treatment groups although the cows fed the HEHP diet averaged 3 kg more milk than the cows on the other treatments (Table 3). Lactose, fat, and protein yields were not different among the treatments.

Table 2: Dry matter intake of cows fed different diets in the close-up dry period.

	HEHP	HELP	LEHP	LELP
DMI, kg/day				
Precalving	12.69[ab]	11.66[b]	13.49[a]	12.79[ab]
Postcalving	17.42[a]	16.41[ab]	15.78[b]	15.21[b]
DMI, % of BW				
Precalving	1.67	1.62	1.83	1.82
Postcalving	2.95	2.90	2.88	2.69

[a,b]Means in the same row with different superscripts differ ($P < 0.05$)

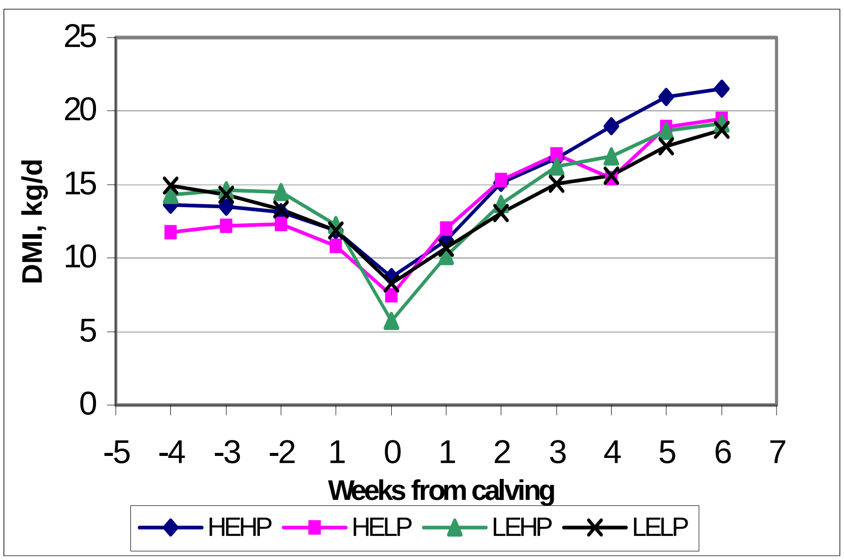

Figure 2: Dry matter intake of cows fed different diets in the close-up dry period.

Table 3: Milk yield and composition of cows fed different diets in the close-up dry period.

	HEHP	HELP	LEHP	LELP
Yield, kg/d				
Milk	37.40	34.38	34.83	34.30
4% FCM	37.23	35.12	36.17	35.74
Fat	1.48	1.43	1.48	1.47
Protein	1.19	1.11	1.13	1.11
Lactose	1.68	1.53	1.55	1.52
Milk composition, %				
Fat	4.01	4.23	4.33	4.33
Protein	3.25	3.29	3.30	3.30
Lactose	4.46	4.45	4.42	4.45

Plasma NEFA were not different among the treatments in both the precalving and postcalving periods, however, there were differences at calving (Figure 3). Non-esterified fatty acids of cows fed the LEHP diet were higher than NEFA of cows on the high energy diets, indicating that these cows mobilized more body fat at calving. There was no difference in NEFA levels of the cows fed the two low energy diets.

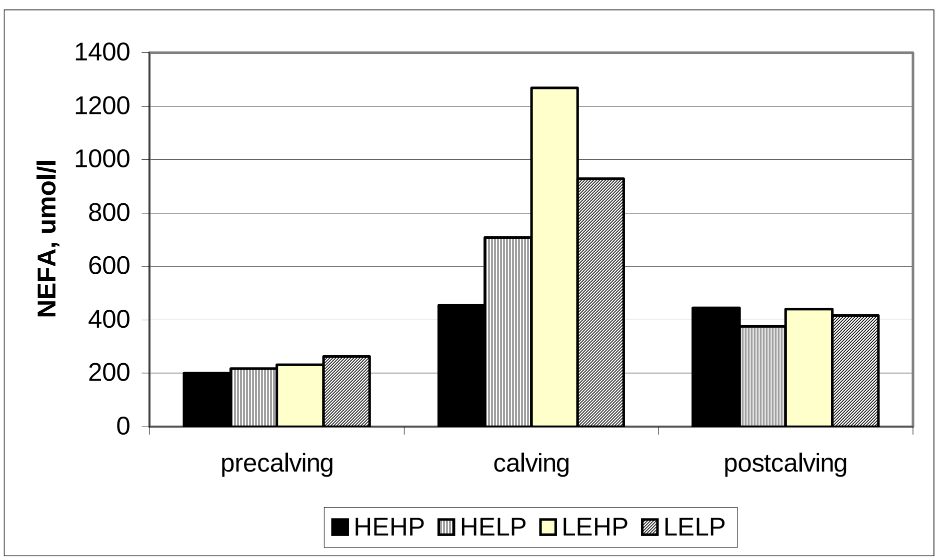

Figure 3: Non-esterified fatty acid concentration of cows fed different diets in the close-up dry period.

Liver triglyceride concentrations, which give an indication of the degree of fatty liver, were not statistically different among the treatment groups, although they were numerically lower at calving for the cows on the high energy diets compared to those on the low energy diets (Figure 4). The large increase in TG levels at calving relative to the pretreatment values demonstrates that fat infiltration of the liver occurs before the high energy demand of lactation even begins. The liver TG levels increase even more during the early weeks of lactation, indicating that the cow is mobilizing even more body fat in support of milk production.

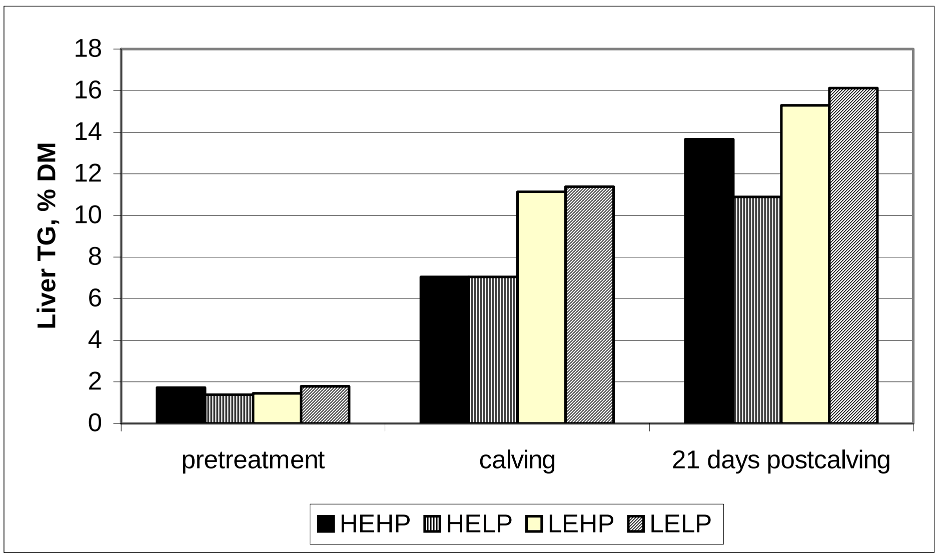

Figure 4: Liver triglyceride concentration of cows fed different diets in the close-up dry period.

▪ Conclusion

Maximizing energy and protein intake during the transition period is paramount to cows making a smooth transition. Increased energy density of the diet helps combat the drop in feed intake that occurs during the 3 weeks before calving, and helps keep cows in positive energy balance. High energy intakes precalving are associated with lower plasma NEFA and liver TG at calving. This is turn should reduce the risk of development of fatty liver and ketosis. Crude protein intake higher than that recommended by NRC may improve milk yield and body condition in the early lactation period.

References

Bertics, S.J., Grummer, R.R., Cadorniga-valino, C. and Stoddard, E.E. 1992. Effect of prepartum dry matter intake on liver triglyceride concentration and early lactation. J. Dairy Sci. 75:1914-1922.

Coppock, C.E., Noller, C.H., Wolfe, S.A., Callahan, C.J. and Baker, J.S. 1972. Effect of forage-concentrate ratio in complete feeds fed ad libitum on feed intake prepartum and the occurrence of abomasal displacement in dairy cows. J. Dairy Sci. 55:783-789.

Curtis, C.R., Erb, H.N., Sniffen, C.J., Smith R.D. and Kronfeld, D.S. 1985. Path analysis of dry period nutrition, postpartum metabolic and reproductive disorders, and mastitis in Holstein cows. J. Dairy Sci. 68:2347-2360.

Dann, H.M., Varga, G.A. and Putnam, D.E. 1999. Improving energy supply to late gestation and early postpartum dairy cows. J. Dairy Sci. 82:1765-1778.

Emery, R.S. 1993. Energy needs of dry cows. In: Proc. Tri-State Dairy Nutr. Conf. Ohio State Univ., Michigan State Univ., and Purdue Univ., Ft. Wayne, IN. pp 35-42.

Fronk, T.J., Schultz, L.H. and Hardie, A.R. 1980. Effect of dry period overconditioning on subsequent metabolic disorders and performance of dairy cows. J. Dairy Sci. 63:1080-1090.

Garnsworthy, P.C. and Jones, G.P. 1987. The influence of body condition at calving and dietary protein supply on voluntary food intake and performance in dairy cows. Anim. Prod. 44:347-353.

Goff, J.P. and Horst, R.L. 1997**.** Physiological changes at parturition and their relationship to metabolic disorders. J. Dairy Sci. 80:1260-1268.

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

Grummer, R.R. 1995. Impact of changes in organic nutrient metabolism on feeding the transition dairy cow. J. Anim Sci. 73:2820-2833.

Grummer, R.R., Bertics, S.J., Lacount, D.W., Snow, J.A., Dentine, M.R. and Stauffacher, R.H. 1990. Estrogen induction of fatty liver in dairy cattle. J. Dairy Sci. 73:1537-1543.

Grummer, R.R., Hoffman, P.C., Luck, M.L. and Bertics, S.J. 1995. Effect of prepartum and postpartum dietary energy on growth and lactation of primiparous cows. J. Dairy Sci. 78:172-180.

Moe, P.W. and Tyrrell, H.F. 1972. Metabolizable energy requirements of pregnant dairy cows. J.Dairy Sci. 55:480-483.

Moorby, J.M., Dewhurst, R.J., and Marsden, S. 1996. Effect of increasing digestible undegraded protein supply to dairy cows in late gestation on the yield and composition of milk during the subsequent lactation. Anim. Sci. (Sofia) 63:201-213.

Putnam, D.E. and Varga, G.A. 1998. Protein density and its influence on metabolite concentration and nitrogen retention by Holstein cows in late gestation. J.Dairy Sci. 81:1608-1618.

Vanderhaar, M.J., Yousif, G., Sharma, B.K., Herdt, T.H., Emery, R.S., Allen, M.S., and Liesman, J.S. 1999. Effect of energy and protein density of prepartum diets on fat and protein metabolism of dairy cattle in the periparturient period. J.Dairy Sci. 82:1282-1295.

Van Saun, R.J., Idleman, S.C., and Sniffen C.J. 1993. Effect of undegradable protein amount fed prepartum on postpartum production of first lactation Holstein cows. J. Dairy Sci. 76:236-244.

Weinstein, I., Soler-Argilaga, C. and Heimberg, M. 1977. Effects of oethynyl estradiol on incorporation of [1-^{14}C]oleate into triglyceride and ketone bodies by the liver. Biochem. Pharmacol. 26:77-80.