TRANSITION COW DRY MATTER INTAKE AND METABOLIC DISORDERS

Ric R. Grummer
Department of Dairy Science
University of Wisconsin-Madison

rgrummer@wisc.edu

For the past decade, many people including myself have challenged dairy producers to maximize feed intake of cows immediately prior to calving to prevent negative nutrient balances and to promote high feed intake after calving. There are both theoretical arguments and experimental evidence that can be forwarded to support the recommendation to maximize feed intake during the pre-fresh transition period. On average, cows experience approximately a 30% reduction in feed intake during the final three weeks of pregnancy. During this time, nutrient requirements are increasing to support fetal and mammary growth. It makes sense to increase nutrient density of the diet during this time. To avoid problems with rumen function, there is an upper limit to which energy density of the diet can be increased. Therefore, it is logical that feed intake must also be maximized to avoid a negative energy balance. Excessive negative energy balance promotes fat mobilization from adipose tissue and may lead to fatty liver, ketosis, and perhaps other postpartum complications.

Evidence to Support Feeding for Maximum Intake

To evaluate the importance of prepartum feed intake, Bertics et al., (1992) compared metabolism and lactation performance of cows that were allowed to voluntarily go off-feed during the last three weeks prior to calving to those that were force-fed via rumen fistulas (see solid and fine dashed curves in Figure 1). After calving both groups of cows were allowed ad libitum consumption of feed and intake did not differ between groups. Cows that were force-fed prior to calving had lower liver triglyceride (fat) at calving and over time produced more milk with a higher fat test (Figure 2 and 3). This data strongly supported the concept that high feed intake prior to calving is essential for optimal animal health and production. We also pooled data from “control” cows from several of our experiments and examined the relationship between voluntary feed intake immediately prior to calving and voluntary feed intake at 21 days post calving.

The relationship was fairly strong (r = 0.54) and reinforced the idea of maximizing feed intake prepartum.

Evidence to Suggest that Maximizing Feed Intake is Not Necessary

During the past few years, there have been several lines of evidence that have made us re-think the original interpretation of the force feeding trial. Anecdotal evidence from the field indicates that there are multiple ways to have a successful transition from the dry period to lactation. Feeding high fiber diets throughout the dry period has been successful for some producers. If maximizing feed intake was the key to successful transition programs, this strategy should fail since numerous studies (Minor et al., 1998, Holcomb et al., 2001, Rabelo et al., 2003) have demonstrated an inverse relationship between dietary fiber and prepartum feed intake.

Heifers consume less feed (even when expressed as a percentage of body weight) than cows yet are much more resistant to developing fatty liver at calving than cows (Moore et al., 2000, Rabelo et al., unpublished). The feed intake curve of a heifer is flatter than for a cow, which means that there is a prolonged period of lower feed intake. Logic would have it that heifers would have more severe fat infiltration of the liver at calving.

Several recent studies have indicated that low feed intake prior to calving is not necessarily detrimental to health and production. The first clue came from Drackely and co-workers at the University of Illinois (Grum et al., 1996). They fed a control diet, a diet with more fiber than the control, or a diet with more fiber but supplemented with fat so that it was isocaloric to the control diet. Treatments were fed from dry-off until one week prior to calving. Cows on the high fiber diet (without fat) had the lowest feed intake yet had the lowest amount of fat in the liver at calving. This was in complete contrast to what I would have predicted. Minor et al. (1998) achieved dramatically higher feed intake (3-4 kg/d) by increasing nonfiber carbohydrate from 24 to 44% in the prefresh diet but did not observe a reduction in liver triglyceride at calving. In our most recent study (Rabelo et al., 2003), we fed diets containing 0.70 or 0.75 Mcal NE_L/d for the final four weeks prepartum. The increase in energy density was obtained by lowering forage and increasing concentrate in the TMR. Despite significantly higher feed intake by heifers or cows consuming the more energy dense diet (Figure 4), liver triglyceride and postpartum lactation performance were not affected by treatment. Florida researchers (Holcomb et al., 2001) conducted an excellent study in which feed intake of pre-fresh transition cows was limited by feed restriction (18 lb/d), by increasing forage content of the diet, or a combination of both (Table 1). Based on prepartum feed intake, one might have expected the cows fed the low forage diet ad libitum to perform the best, but this was clearly not the case.

A common observation among these studies is that lower feed intake coincides with a flatter intake curve (see coarse dashed curve in Figure 1, Figure 4). These observations have led us to reconsider the interpretation of the force feeding study by Bertics et al. (1992). *Was the benefit of force feeding due to maximization of feed intake or was it due to the elimination of feed intake depression?* Cows represented by the coarse dashed curve (Figure 1) do not have high feed intake, but they have very little depression in feed intake. That makes them in common with cows represented by the solid curve.

We composited data from three of our most recent trials (Minor et al., 1998; Hayirli et al., 2001; Rabelo et al., 2003) to examine how dry matter intake (DMI) during the prepartum period may influence plasma NEFA, liver triglyceride (TG) and postpartum DMI and milk production (Grummer et al., 2004). The pooled data set included 40 nulliparous and 122 primi- or multiparous Holstein cows. Cows were grouped in BCS categories as normal (BCS < 4.0; n = 136) or obese (BCS ≥ 4.0; n = 26). The BCS data was collected between 28 and 21 d prepartum. Prepartum DMI change (% BW; DMIBWΔ) was calculated as DMI (% BW) at 1 d before parturition minus DMIBW. Prepartum DMI (% BW; DMIBW) was calculated as average DMI (% BW) from 21 to 14 d before parturition. We chose d 21 to 14 rather than d 21 to 1 prior to parturition because the latter parameter would encompass DMI change, which is most prominent during the final two weeks prior to calving. Data were analyzed by regression. One model included fixed effects of parity, BCS, DMIBW, and random effects of treatment within study. In the second model, DMIBWΔ replaced DMIBW. Originally, data were fitted to a model testing for interactions between DMIBW or DMIBWΔ and parity and body condition (i.e., unequal slopes). There were no significant interactions ($P > 0.15$), thus the interaction terms were removed from the final models. Response variables included plasma NEFA concentrations and liver TG content at 1 d postpartum, and milk yield and DMI (%BW) averaged over the first 28 d postpartum.

When DMIBW was included as an independent variable, plasma NEFA and liver TG were not affected (Table 2, Figure 5 and 6). Conversely, if DMIBWΔ replaced DMIBW as an independent variable, NEFA and TG were affected; the more negative the change in prepartum DMI, the greater the concentration of NEFA and TG. This suggests that change in feed intake rather than absolute intake during the prepartum transition period may be the best predictor of plasma NEFA and metabolic disorders that have been associated with elevated NEFA (Dyke, 1995, Cameron et al., 1998). In contrast, DMIBW, but not DMIBWΔ, was a predictor of postpartum DMI or milk yield (Table 2). This was surprising because elevated plasma NEFA and liver TG at 1 d postpartum might be expected to negatively influence subsequent feed intake and milk production. However, the great majority of cows represented in this data set were healthy; metabolic parameters may not have varied sufficiently to affect milk production.

Slope of regression lines did not vary according to BCS or parity (Figure 5 and 6). However, there were significant effects of BCS and parity on dependant variables; the level of significance varying depending on whether DMIBW or DMIBWΔ was included in the model (Table 2). Cows with BCS ≥ 4 had higher plasma NEFA and liver TG and lower postpartum DMI and milk yield. Nulliparous animals had lower plasma NEFA, liver TG, postpartum DMI and milk yield. Lower susceptibility of nulliparous animals and higher susceptibility of overconditioned cows to fatty liver has previously been reported (Reid et al., 1986; Moore et al., 2000).

From this data set, it is not possible to conclude that feeding for high DMI prior to calving will result in high DMI and milk yield postcalving. An alternative interpretation is that cows that have a high genetic potential to consume feed do so at all stages of the gestation-lactation cycle. Nevertheless, these results support achieving high DMI by prepartum transition cows. There may be situations in which an inverse relation between pre- and postfresh DMI occurs. For example, feed restriction prepartum may result in a compensatory increase in feed intake postpartum (Douglas et al., 1998).

Results from this analysis suggest that decreases in prepartum feed intake should be avoided to minimize the likelihood of elevated plasma NEFA and liver TG. There was no apparent ramification of changes in prepartum feed intake on milk yield of cows used in this analysis. However, other reports (Dyke, 1995, Cameron et al., 1998) suggest that elevated plasma NEFA or liver TG during the periparturient period are associated with increased incidence of metabolic disorders.

Implications

It is important to note that high dry matter intake by pre-fresh transition cows should not be discouraged. If I had to choose between consistent high feed intake (e.g. the solid curve in Figure 1), or consistent low feed intake (e.g. the coarse dashed curve), I would choose the former. However, if one is unable to manage to prevent a large decline in feed intake near calving, then feeding a higher fiber diet to restrict intake might be advised. A wise old coach once pointed out to his undersized football team: "the bigger they are the harder they fall". The higher the feed intake of a cow as she approaches calving, the greater the potential decline in intake!

Literature Cited

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

Cameron, R. E., P. B. Dyke, T. H. Herdt, J. B. Kaneene, R. Miller, H. F. Buckholz, J. S. Liesman, M. J. Vandehaar, and R. S. Emery. 1998. Dry cow diet, management, and energy balance as risk factors for displaced abomasum in high producing dairy herds. J. Dairy Sci. 81:132-139.

Douglas, G. N., J. K. Drackley, T. R. Overton, and H. G. Bateman. 1998. Lipid metabolism and production by Holstein cows fed control or high fat diets at restricted or ad libitum intakes during the dry period. J. Dairy Sci. 81(Suppl. 1):295. Abstr.

Dyke, P. B. 1995. The association of prepartum non-esterified fatty acids and body condition with peripartum health problems. M. S. Thesis, Michigan State Univ., East Lansing.

Grum, D. E., J. K Drackley, R. S. Younker, D. W. Lacount, and J. J. Veenhuizen. J. 1996. Production, digestion, and hepatic lipid metabolism of dairy cows fed increased energy from fat or concentrate. Dairy Sci. 79:1836.

Grummer, R. R., D. G. Mashek, and A. Hayirli. 2004. Dry Matter Intake and Energy Balance in the Transition Period. Vet. Clinics North Amer. 20:447-470.

Hayirli, A., D. R. Bremmer, M. T. Socha, and R. R. Grummer. 2001. Effect of chromium supplementation on production and metabolic parameters in periparturient dairy cows. J. Dairy Sci. 84:1218-1230.

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.

Minor, D. J., S. L. Trower, B. D. Strang, R. D. Shaver, and R. R. Grummer. 1998. Effects of nonfiber carbohydrate and niacin on periparturient metabolic status and lactation of dairy cows. J. Dairy Sci. 80:189.

Moore, S. J., M. J. VandeHaar, B. K. Sharma, T. E. Pilbeam, D. K. Beede, H. F. Bucholtz, R. L. Horst, and J. P. Goff. 2000. Effect of altering cation-anion difference and energy metabolism in peripartum cows. J. Dairy Sci. 83:2095-2104.

Rabelo, E., R. L. Rezende, S. J. Bertics, and R. R. Grummer. 2003. Effects of transition diets varying in dietary energy on lactation performance and ruminal parameters of dairy cows. J. Dairy Sci. 86: 916-925.

Reid, I. M., C. J. Roberts, R. J. Treacher, and L. A. Williams. 1986. Effect of body condition at calving on tissue mobilization, development of fatty liver and blood chemistry of dairy cows. Anim. Prod. 43:7-15.

Table 1. Response of cows fed different amounts of forage in the diet and offered restricted or ad libitum feed intake prior to calving (Holcomb et al., 2001)

	Low forage Ad libitum	Low forage Restricted	High forage Ad libitum	High forage Restricted
Prepartum DMI, kg/d	14.1	7.9	10.7	8.1
Postpartum DMI, kg/d	20.5	21.3	21.2	21.4
NEFA, mEq/L[1]	650	674	908	799
Milk, kg/d	29.9	36.0	35.8	34.4
Fat, %[2]	3.45	3.05	3.39	3.15
Protein, %	3.07	3.06	3.00	2.99

[1] Forage level effect, $P < 0.05$

[2] Level of feeding effect, $P < 0.05$

Table 2. Analysis describing the relationship between response variables (NEFA, liver TG, postpartum DMI and milk) and DMIBW or DMIBWΔ and body condition and parity. Intercept adjustments are shown for cows with BCS ≥ 4.0 and nulliparous animals

	NEFA (d 1) (μEq/L)	Liver TG (d 1) (% DM)	Postpartum DMI[1] (% BW)	Milk[1] (kg/d)
DMIBW[2]				
Intercept	768.5 (192.3)	11.39 (3.30)	1.64 (0.23)	30.37 (2.43)
Slope	-79.1 (84.1)	-1.53 (1.53)	0.33 (0.09)***	3.48 (1.19)***
BCS ≥ 4.0	136.2 (79.4)*	2.42 (1.50)	-0.32 (0.08)***	-1.09 (1.18)
Nulliparous	-212.3 (76.3)***	-6.13 (1.35)***	-0.18 (0.08)**	-10.67 (1.09)***
DMIBWΔ[3]				
Intercept	454.4 (75.7)	5.20 (1.19)	2.30 (0.17)	36.72 (1.04)
Slope	-172.0 (58.2)***	-4.96 (1.00)***	0.05 (0.07)	-0.66 (0.87)
BCS ≥ 4.0	131.4 (75.8)*	2.53 (1.37)*	-0.39 (0.09)***	-2.01 (1.16)*
Nulliparous	-192.7 (73.9)**	-4.67 (1.17)***	-0.33 (0.08)***	-11.97 (1.03)***

[1] Averaged over the first 28 d postpartum.

[2] DMIBW = DMI (% BW) averaged from 21 to 14 d prepartum.

[3] DMIBWΔ = DMI (% BW) at 1 d prepartum minus DMIBW.

*$P < 0.10$; **$P < 0.05$; ***$P < 0.01$

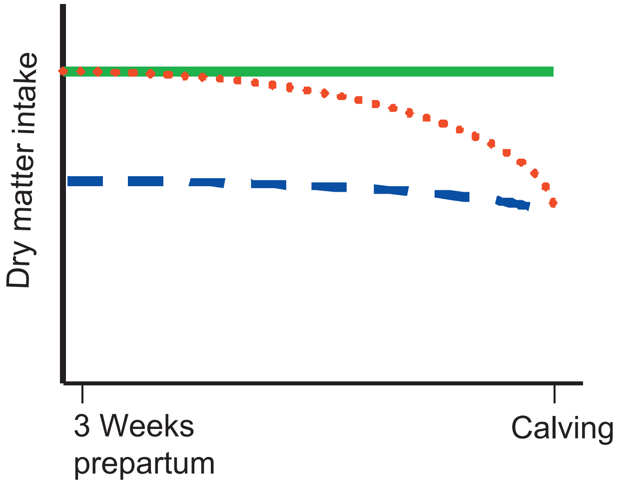

Figure 1. Feed intake patterns of cows that are force fed (solid line), allowed to voluntarily reduce feed intake (fine dashed line), or limit fed due to feed restriction or feeding higher fiber diets (course dashed line) (Bertics et al., 1992)

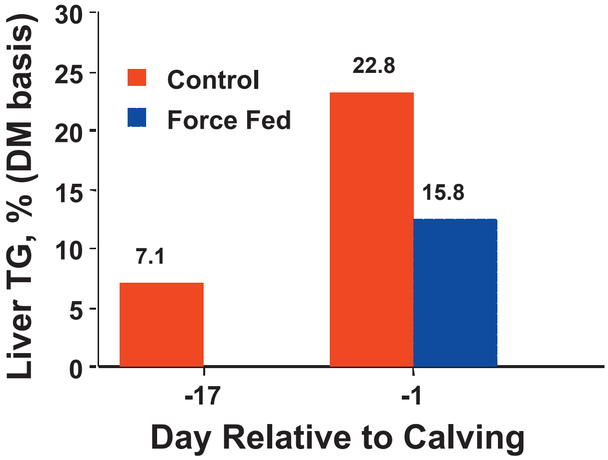

Figure 2. Liver triglyceride (TG) before and after cows were force fed or allowed to voluntarily decrease feed intake prior to calving (Bertics et al., 1992)

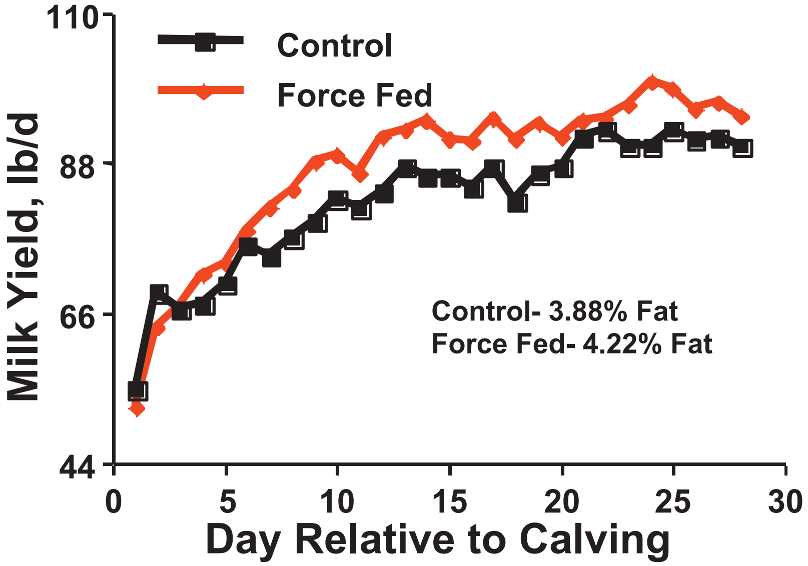

Figure 3. Milk production and fat percentage after cows were forced fed or allowed to voluntarily decrease feed intake prior to calving (Bertics et al., 1992)

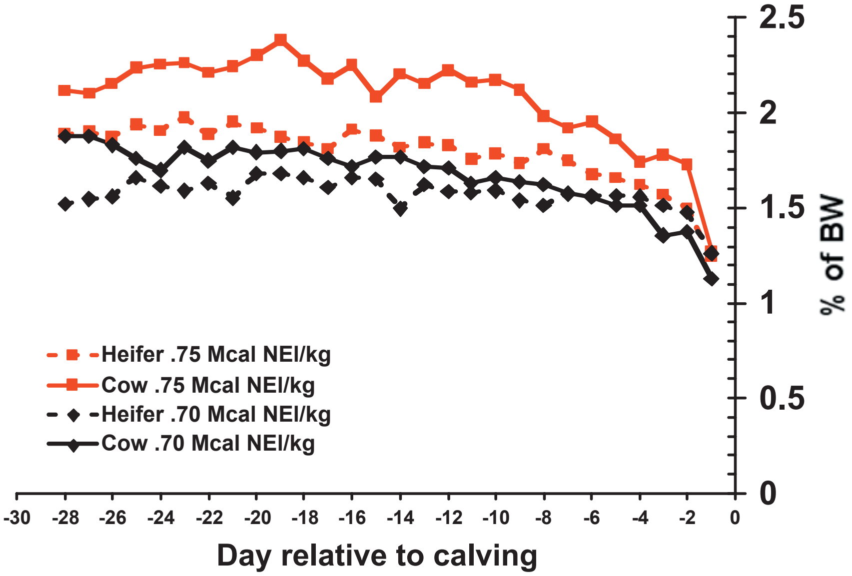

Figure 4. Prepartum feed intake of cows fed diets with varying nonfiber carbohydrate (NFC) (Rabelo et al., 2003)

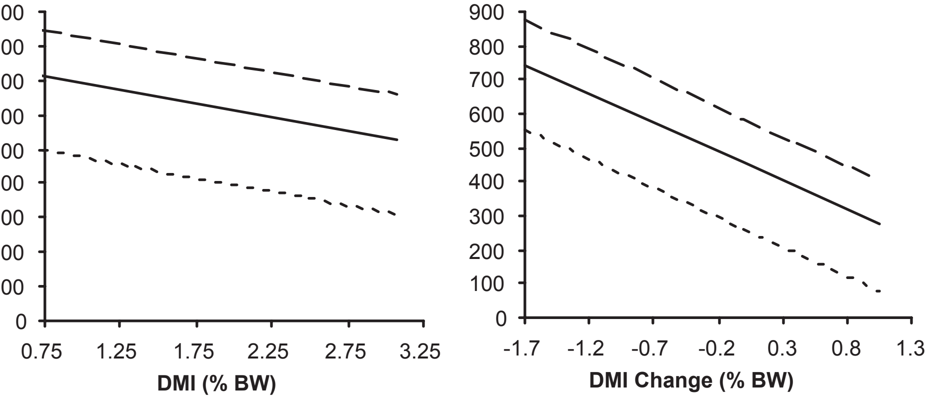

Figure 5. Effects of prefresh DMI or DMI change on plasma nonesterified fatty acid (NEFA) concentrations at 1 d after calving

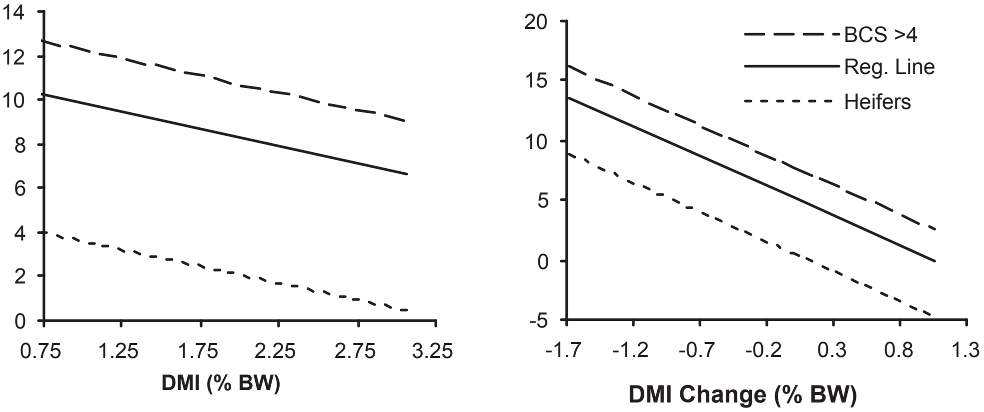

Figure 6. Effects of prefresh DMI or DMI change on liver triglyceride (TG) concentrations at 1 d after calving