PREPARTUM FEED INTAKE OF DAIRY COWS AND EFFECT ON SUBSEQUENT LACTATION PREFORMANCE

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INTRODUCTION

Grummer (1995) defined the transition period as 3 weeks prepartum to 3 weeks postpartum. Metabolic changes that occur during the prepartum transition period are unparalleled by any other stage of the lactation cycle. Plasma insulin decreases and growth hormone increases from late gestation to early lactation, with spikes of both occurring at parturition (Kunz et al., 1985). Progesterone is elevated during gestation and estrogen increases during late gestation, with dramatic reduction of both hormones occurring at parturition (Chew et al., 1979). Bauman and Currie (1980) described homeorhesis as the coordinated control in the metabolism of body tissues necessary to support a physiological state. Regulation of nutrient partitioning during pregnancy involves homeorhetic controls arising from the conceptus. Coordinated events in lipid, carbohydrate, protein, and mineral metabolism are important homeorhetic controls of nutrient partitioning that are necessary precursors for milk synthesis.

In addition to changing hormonal profiles and nutrient partitioning, over one-half of fetal growth occurs between 220 and 280 days of gestation (Prior and Laster, 1979), which coincides with a 60 day dry period. While nutrient demand is increasing, dry matter intake (DMI) of Holstein cows typically declines 30% the last three weeks of gestation (Grummer, 1995). The magnitude of decline in DMI has important implications on health and productivity of the cow in the ensuing lactation. In a review, Grummer (1995) reported that DMI 1 day prepartum was highly correlated to liver triglyceride ($r = -0.45$) and plasma non-esterified free fatty acids (NEFA) ($r = -0.44$), and DMI the day prior to parturition was also highly correlated with DMI 21 days postpartum ($r = 0.53$). Most health problems in dairy cattle occur in early lactation and have been associated with relatively low intake prior to parturition (Zamet et al., 1979). Therefore, a priority in feeding transition cows should be to maximize prepartum feed intake.

PREPARTUM INTAKE

Several experiments conducted over a decade ago, before the heightened interest in transition cows, does not support the premise of maximizing prepartum DMI. Hernandez-Urdaneta et al. (1976) offered Holstein cows one of two diets 28 d prepartum to 4 d postpartum: 53% NDF or 50% NDF. Prepartum DMI was greater for cows consuming 50% NDF (10.57 kg/d, 1.80% BW) compared to 53% NDF (9.31 kg/d, 1.61% BW). Postpartum DMI and milk yield did not differ between treatments. However, the difference in prepartum DMI was numerically small, most likely due to similar fiber levels of treatments. Kunz et al. (1985) fed cows according to requirement or *ad libitum* from 70 to 5 d prepartum. Prepartum DMI was greater for cows consuming *ad libitum* (11.9 vs 7.3 kg/d) and plasma NEFA was lower (120 vs 210 μmol/l) compared to cows fed at requirement. Postpartum DMI and milk yield were similar for treatments. Boisclair et al. (1986) fed cows according to requirement or *ad libitum* beginning 8 weeks prepartum. Restricting prepartum DMI did not affect DMI and milk yield through week 12 postpartum. Based on results of Kunz et al. (1985) and Boisclair et al. (1986), restricting prepartum DMI does not affect DMI and milk yield in early lactation.

However, two noteworthy factors have changed in 15 years: nutrient requirements have been updated (National Research Council (NRC), 2001); and annual production per cow has increased 2,300 kg. Several recent studies have examined the effect of prepartum diet on subsequent lactation performance. Minor et al. (1998) fed diets containing either 50% or 30% NDF beginning 19 d prepartum. Prepartum DMI was greater (12.8 vs 10.2 kg/d; 1.87 vs 1.48% of BW) and plasma NEFA was lower for cows fed 30% NDF. Although postpartum parameters were confounded due to varying NDF concentrations of postpartum diets, postpartum DMI did not differ between treatment groups. Vandehaar et al. (1999) fed diets with 52%, 40%, or 30% NDF beginning 28 d prepartum. Dry matter intake tended to increase as NDF decreased (11.0, 11.6, and 12.5 kg/d for 52%, 40%, and 30% NDF, respectively), but postpartum DMI and milk yield was similar across treatments. French et al. (1999) offered cows one of four diets containing 56%, 47%, 38%, or 28% NDF beginning 30 d prepartum. Prepartum DMI increased linearly as diet NDF decreased (10.1, 11.9, 13.3, and 15.4 kg/d for 56%, 47%, 38%, or 28% NDF, respectively). Although postpartum DMI did not differ, milk yield tended to increase as prepartum diet NDF decreased. An eloquent study was recently reported by Holcomb et al. (2001). Diets containing 44% and 39% NDF were restricted (8.2 kg/d) or offered *ad libitum* beginning 28 d prepartum. Prepartum DMI differed and was 8.1 and 7.9 kg/d for restricted diets containing 44% and 39% NDF, respectively, and 10.7 and 14.1 kg/d for *ad libitum* diets containing 44% and 39% NDF, respectively. Prepartum treatments did not affect postpartum DMI and milk yield. The experimental design and results of Holcombe et al. (2001) are important for several reasons. The experiment combined restricted and *ad libitum* intakes with diets differing enough in NDF to elicit a feed intake response.

Based on the results of the seven trials discussed above (Table 1), regulation of prepartum DMI through feeding level or fiber level does not influence postpartum DMI and milk yield. How should the discrepancy between these results and statements about maximizing prepartum DMI be reconciled? Given the correlations between prepartum DMI and liver triglyceride, plasma NEFA, and postpartum DMI (Grummer, 1995), it would seem advisable to concentrate a great deal on prepartum DMI. Results from our lab (Figure 1) show a positive correlation between DMI 1 wk prepartum and DMI 1 wk postpartum for Holsteins (r = 0.52; $P < 0.01$; n = 30) and Jerseys (r = 0.54; $P < 0.01$ n = 28). These results are similar to Grummer (1995) and suggest a cause and effect relationship. However, removing the cows that received >38% NDF from French et al. (1999), increased the correlation of DMI 1 wk prepartum and DMI 1 wk postpartum from 0.45 ($P < 0.01$; n = 22) to 0.60 ($P < 0.01$; n = 13). Indicating that prepartum DMI, when limited by fill is not an accurate predictor of postpartum DMI.

Appetite during the entire dry period may be an indicator of appetite in the subsequent lactation. Comparing DMI in the three successive weeks prior to parturition with DMI the week after parturition indicates that this is unlikely. The correlation between DMI 1 wk postpartum and DMI 1 wk prepartum, 2 wk prepartum, and 3 wk prepartum was 0.52 0.51, and 0.37, respectively. Dry matter intake one to two weeks prior to parturition is a better indicator of postpartum DMI compared to DMI earlier in the dry period.

BREED INTAKE DIFFERENCES

Using data from French et al. (1999), the correlation between DMI 1 wk prepartum and DMI 1 wk postpartum was 0.45 ($P < 0.05$; n = 22) for Holsteins and 0.42 ($P < 0.05$; n = 22) for Jerseys. As mentioned above, removing cows that consumed diets containing greater than 38% NDF increased the correlation to 0.60 ($P < 0.05$; n = 13) for Holsteins. When these cows were removed for the Jersey breed, the correlation decreased to 0.02 ($P < 0.95$; n = 11). The breed difference can be explained by two factors, which are probably interrelated: magnitude of depression in prepartum DMI and plasma NEFA.

Results from our lab (French et al., 1999; French, 2002), shown in Figure 2, show a negative correlation between DMI and plasma NEFA 3 d prior to parturition in Holsteins (r = – 0.68; $P < 0.01$; n = 28) and Jerseys (r = – 0.45; $P < 0.05$; n = 24). Plasma NEFA was consistently lower prepartum, and the day of parturition and the day after parturition for Jerseys compared to Holsteins (Figure 3). Prepartum DMI differences also exist between breed (Figure 4). The magnitude of depression in DMI the last 3 weeks of gestation was less for Jerseys (15%) compared to Holsteins (45%) ($P < 0.05$). Elevated NEFA in Holsteins was not due to negative energy balance based on NRC (2001) metabolizable energy requirement for pregnant cows. Holsteins did not enter negative energy balance until the day prior to parturition. Continuous long-term infusion of long-chain fatty acids has been shown to cause inappetance in sheep (Vandermeerschen-Doizé and Paquay, 1984). The greater decline in prepartum DMI for Holsteins compared to Jerseys may be attributable to differences in plasma NEFA.

MECHANISM OF PREPARTUM DMI DEPRESSION

Several mechanisms may be involved in prepartum DMI depression. Some have suggested that the depression may be due to physical compression of the rumen by the growing fetus (Ingvartsen and Anderson, 2000). Postpartum DMI should increase rapidly after calving if prepartum DMI depression is due to compressed rumen volume. However, postpartum DMI does not increase rapidly in relation to milk yield and other factors, such as metabolic and endocrine, must be controlling prepartum DMI depression. Adipose tissue mobilization during late pregnancy causes a rise in circulating levels of NEFA and ketones. A negative relationship between plasma NEFA and DMI during the prepartum period has been described above. Subcutaneous injections of β-hydroxybutyrate have been shown to cause intake depression in rats (Fisler et al., 1995). The reproductive hormones, estrogen and progesterone, play a role in regulation of appetite. Intravenous infusion of 17-estradiol decreased both DMI and milk yield in dairy cattle (Grummer et al., 1990). Progesterone has not been shown to have a direct effect on intake, but has been reported to block the effects of estrogen in dairy cattle (Muir et al., 1972). Grummer (1995) suggested that estrogen or estrogen to progesterone ratio might influence prepartum DMI.

Jersey Prepartum DMI Equation

French et al (2002) developed a prepartum DMI equation similar to NRC (2001) utilizing 69 multiparious Jerseys receiving one of eight diets at three universities. Diets ranged from 12.1 to 15.1% CP and 28.0 to 40.3% NDF. The equation was DMI (% of BW) = $a + be^{(kt)}$; where a is asymptotic intercept at time infinity, b is magnitude of depression in DMI, t is day prepartum, and $e^{(kt)}$ is the shape of the curve. Prepartum DMI as predicted by the equation is shown in Figure 5 and was DMI (% of BW) = $2.35 - 0.53e^{(-0.16t)}$. Comparing the Jersey equation to NRC (2001), prepartum DMI declined 19% for Jerseys and 32% for Holsteins. In addition to the magnitude of decline in DMI as parturition approaches, the NRC (2001) equation underpredicts DMI of Jersey cows by 25%.

On average, daily consumption of DM by Jersey cows should be 2.21% of BW. Although expression of DMI as a percentage of BW appears reasonable, the correlation (r = – 0.39) between DMI (% of BW) and BW indicates that DMI is overestimated as BW increases. Body condition, rather than body size, is affecting BW. Body weight is not an appropriate covariate to adjust DMI for differences in BW, especially for higher BW. Therefore, DMI should be expressed and evaluated in kilograms or pounds per day. As shown in Figure 6, prepartum DMI ranges from 9 to 12 kg/d and averages 11 kg/d for multiparious Jersey cows the last three weeks of gestation.

Summary

Should emphasis be placed on maximizing prepartum DMI? Notwithstanding the strong positive correlation between prepartum and postpartum DMI, the answer is no. Limiting prepartum DMI did not affect postpartum DMI and milk yield (Kunz et al., 1985; Minor et al., 1998; French et al., 1999; Vandehaar et al., 1999; Holcomb et al., 2001). Cows should be offered a balanced ration that meets nutrient requirements at the level of DM consumed by a group or pen of cows.

Future research should focus on the cause and magnitude of decline in prepartum DMI, since DMI the two weeks prior to parturition is strongly correlated to postpartum DMI. A promising area that needs attention is lipid mobilization, due to the relationship between prepartum DMI and NEFA. Although lipid mobilization cannot be eliminated prior to parturition, means to minimize NEFA may lead to improved prepartum DMI and therefore improved postpartum DMI and milk yield. Breakthroughs may occur in research areas other than nutrition, such as genetics. Evidence suggests that cows have been selected to mobilize lipid stores to support milk production and based on prepartum plasma NEFA, mobilization begins prior to parturition. There is a strong genetic correlation between lifetime yield and the type traits, angularity (0.53) and dairy character (0.53) (Klassen et al., 1992). A useful translation is cows that are thin or possess the ability to mobilize fat stores produce more milk than cows that are fat. However, selection pressure on the ability to mobilize lipid stores may be counterproductive. Genetic correlations between feed intake and yield suggest that the correlated response in feed intake from selection on yield alone can cover only 40% of the extra requirements for increased yield (Van Arendonk et al., 1991). Veerkamp (1998) questions whether this apparent improvement in gross efficiency is due to improved feed efficiency or whether the efficiency is just due to greater negative energy balance in early lactation.

Prepartum DMI will continue to be a pervasive topic. Expected improvements in milk yield and health in the subsequent lactation will drive research in prepartum diet modification and supplementation. Elucidating factors that control prepartum feed intake will also lead to a better understanding of postpartum feed intake. We need only look to human food intake research and the recent discovery of the hormone PPY to realize the potential and breadth of possibilities that remain in transition cow nutrition.

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Table 1. Effect of prepartum diet and/or level of intake on prepartum DMI, postpartum DMI, and milk yield.

Source	Feeding Level[1]	CP % DM	NDF % DM	Prepartum DMI, kg/d	Postpartum DMI, kg/d	Milk Yield, kg/d
Holcomb et al. (2001)	R	13.7	44.2	8.1	21.4	35.8
	F	13.7	44.2	10.7	21.2	34.4
	R	13.7	39.2	7.9	21.3	29.9
	F	13.7	39.2	14.1	20.5	36.0
	P <			0.05	NS[2]	NS
Vandehaar et al. (1999)	F	12.2	51.5	11.0	15.9	34.0
	F	14.2	40.0	11.6	16.1	33.8
	F	16.2	40.6	11.7	16.0	34.1
	F	15.9	30.2	12.5	15.3	33.8
	P <			0.11	NS	NS
French et al. (1999)	F	12.1	56.0	10.1	24.5	39.7
	F	12.1	47.0	11.9	22.2	40.6
	F	12.1	38.0	13.3	23.9	42.8
	F	12.1	28.0	15.4	25.4	43.8
	P <			0.05	NS	0.1
Minor et al. (1998)	F	14.4	48.9	10.1	21.3	
	F	13.2	29.5	12.8	20.8	
	P <			0.05	NS	
Boisclair et al. (1986)	R	11.1	34.8	NR[3]	18.0	
	F	11.1	21.5	NR	18.0	
	P <				NS	
Kunz et al. (1985)	R	NR	NR	7.3	15.8	
	F	NR	NR	11.9	15.6	
	P <			0.05	NS	
Hernandez-Urdaneta et al. (1976)	F	14.0	53.4	9.3	14.4	
	F	14.1	49.7	10.6	15.3	
	P <			0.05	NS	

[1]R = restricted, F = free choice or *ad libitum*
[2]Not Significant
[3]Not Reported

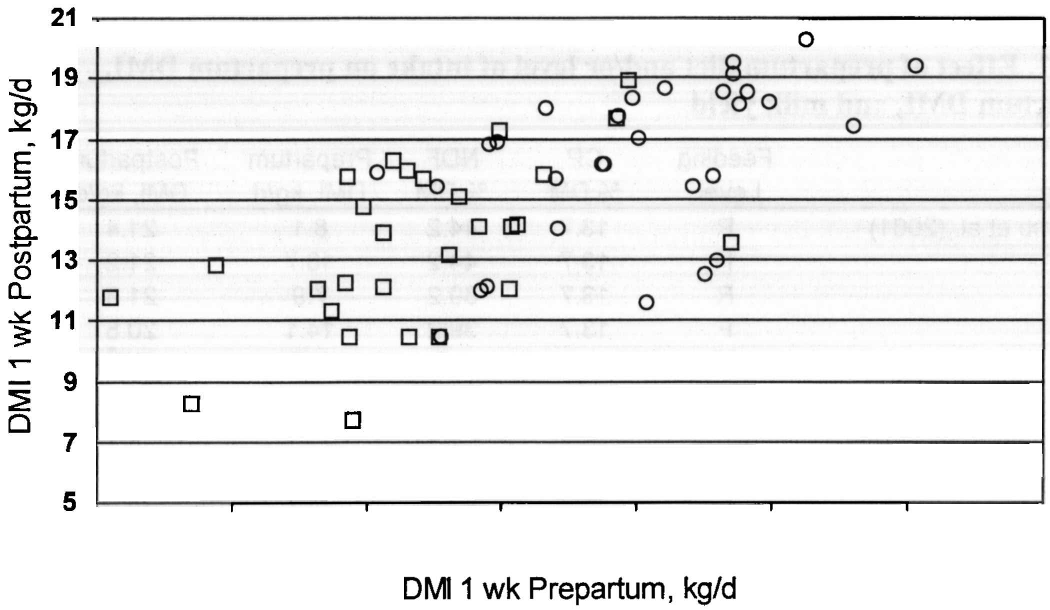

Figure 1. Effect of DMI the week prior to parturition on DMI the week after parturition for Holsteins (○; r = 0.52; $P < 0.01$; n = 30; DMI 1 wk postpartum (kg/d) = 0.72 x DMI 1 wk prepartum + 6.9) and Jerseys (□; r = 0.54; ; $P <$ 0.01 n = 28; DMI 1 wk postpartum (kg/d) = 0.75 x DMI 1 wk prepartum + 6.1).

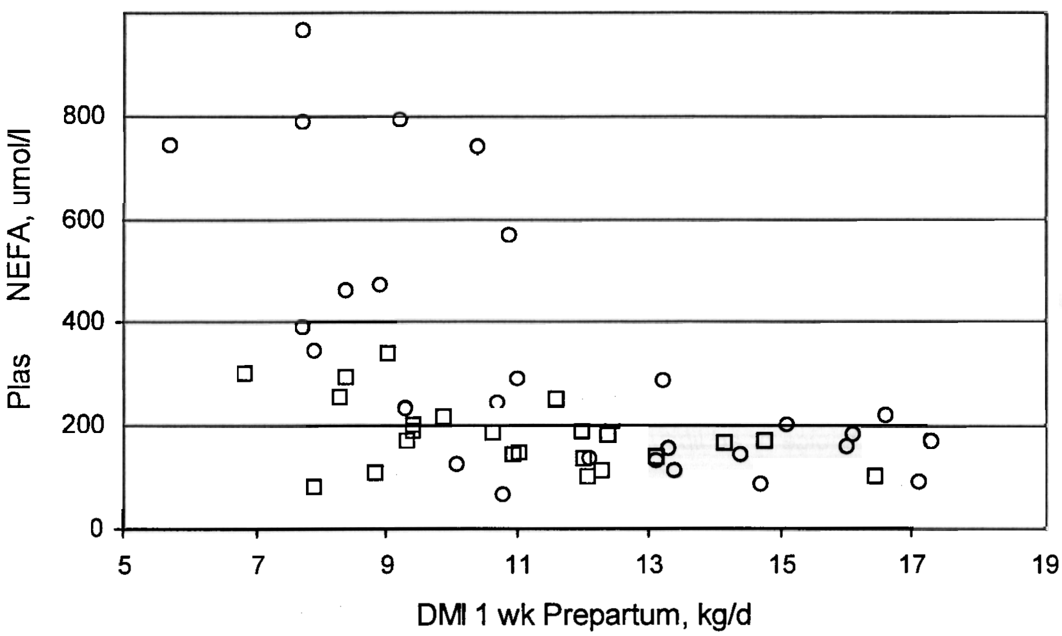

Figure 2. Relationship of DMI and plasma NEFA 3 d prior to parturition in Holsteins (○; r = – 0.68; $P < 0.01$; n = 28) and Jerseys (□; r = – 0.45; $P <$ 0.05; n = 24).

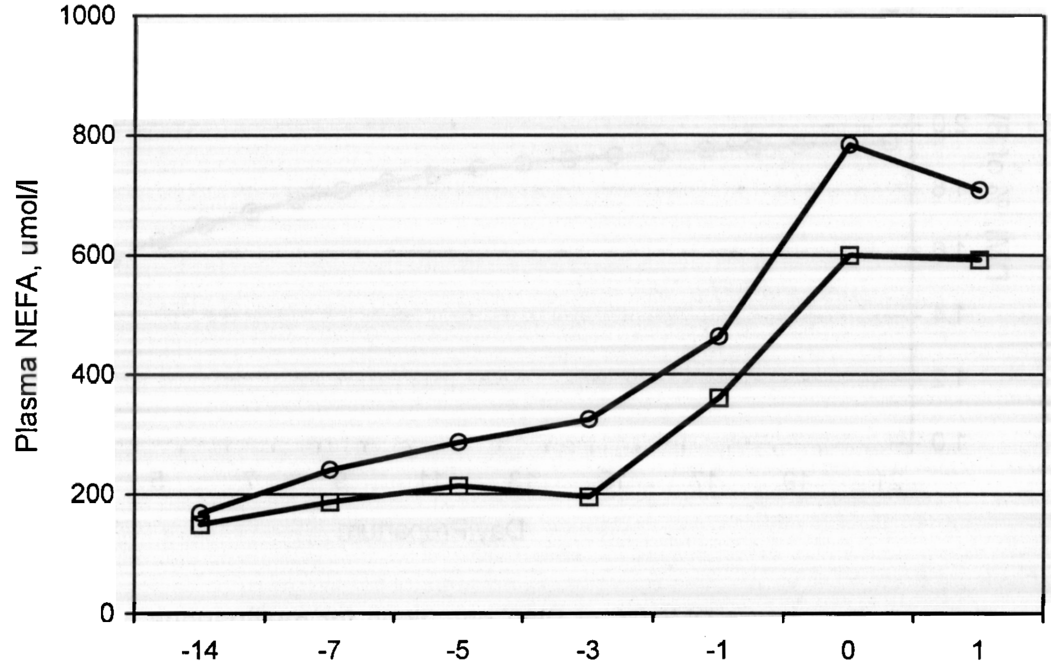

Figure 3. Plasma NEFA for Holstein (○; n = 41) and Jersey (□; n = 38) cows ($P < 0.01$).

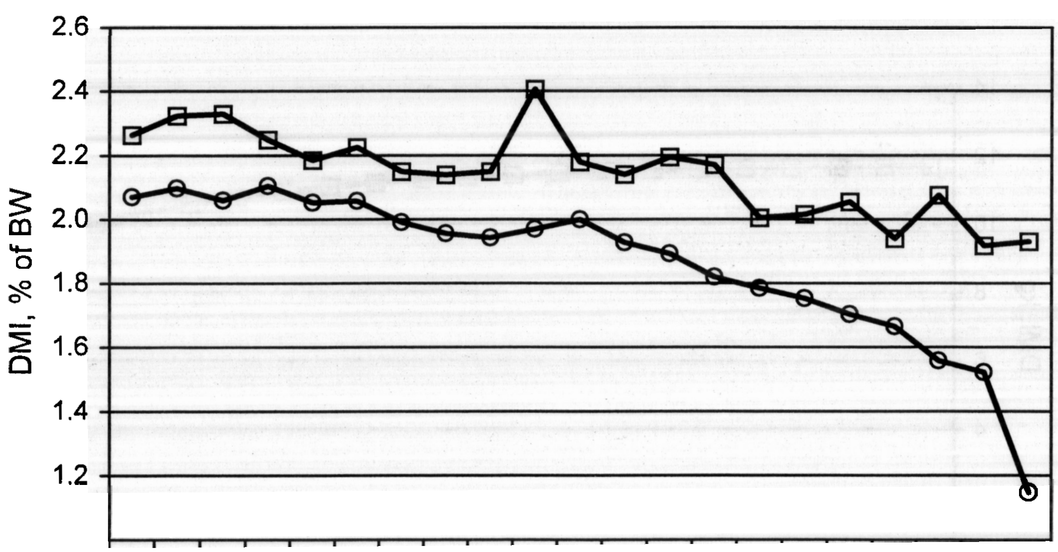

Figure 4. Prepartum DMI for Holstein (○; n = 30) and Jersey (□; n = 25) cows (Breed x Day, $P < 0.05$).

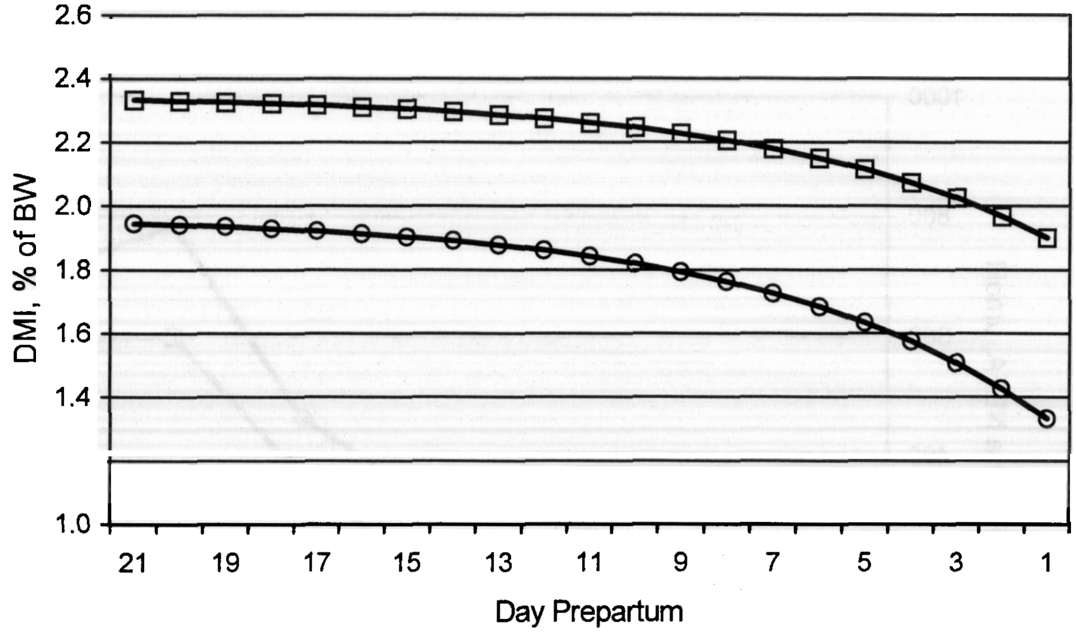

Figure 5. Prepartum DMI (% of BW) equations for multiparious Holstein (○) (NRC, 2001) and Jersey (□) cows.

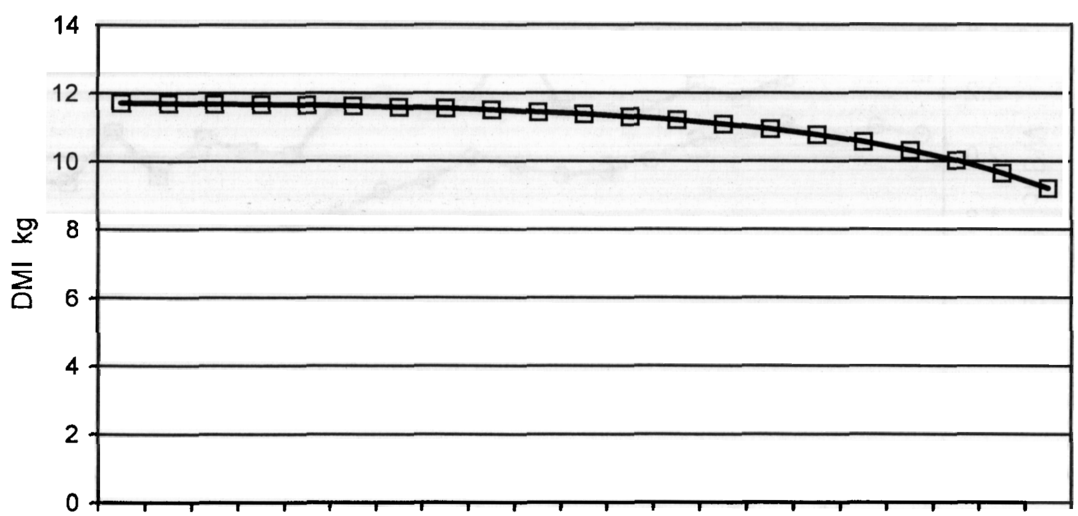

Figure 6. Prepartum DMI for multiparious Jersey cows the last three weeks of gestation.