Prepartum Feeding Strategies for Greater Postpartum Success

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Take Home Message

- Isocaloric diets with 30% of dry matter as high quality chopped orchard grass resulted in higher postpartum DMI during the first month of lactation and greater milk yield on week 1 compared with diets containing 30% chopped wheat straw.
- Milk yield tended to be higher for wheat straw vs. low quality grass hay and wheat straw also had lower postpartum NEFA, higher liver glycogen and tended to have lower liver triglyceride:glycogen.
- Supplementation with sugar (molasses) during the first 60 days in milk decreased postpartum DMI and energy balance compared with starch (corn) supplementation but did not affect yield of milk or 3.5% fat corrected milk yield resulting in an increase in dairy efficiency.
- Feeding negative DCAD (-15 mEq/100 g) for 21 or 42 d prepartum utilizing an acidified fermentation product positively affected calcium homeostasis, postpartum DMI, and milk production in multiparous cows.
- Multiparous cows (N = 120) fed moderate energy high forage diets prepartum for a 42 d dry period averaged 8.0 kg of colostrum.
- Colostrum yield was positively correlated with calf body weight but no significant correlations were found among colostrum yield and prepartum dietary starch, sugar, protein or DCAD.
- Pre- and postpartum serum NEFA and liver triglycerides were positively correlated with colostrum yield.
- Colostrum yield may be a functional on farm predictor of cows at risk for ketosis and fatty liver.

Introduction

The transition period for dairy cows, typically defined as 3 weeks pre-calving through 3 weeks post-calving, is marked with considerable physiological changes associated with the production of colostrum, calving and copious milk secretion. Successful navigation through this period is critically important to the health and performance of the cow in early lactation and has significant impact on reproductive performance, health, and profitability of the cow. Main goals of this period are too; 1) produce adequate amounts of high quality colostrum, 2) give birth to a healthy calf; 3) produce large amounts of milk; 4) maintain health and reproductive efficiency of the cow.

Years of research have focused on nutrition and management strategies to reduce stress during this important time period. Many researchers recognized the need to minimize the mobilization of body fat and prevent fatty liver, ketosis and related metabolic and immune disorders. Several studies (Grum et al., 1996; Rukkwamsuk et al., 1998; 1999; Herdt, 2000; Dann et al., 2006; Douglas et al., 2006) have demonstrated that overconsumption of energy during the dry period can be detrimental to cow health and performance. Overconsumption of energy during the dry period has been demonstrated to result in decreases in DMI as calving approaches compared with cows fed moderate energy diets (Agenäs et al., 2003; Dann et al., 2006; Douglas et al., 2006; Guo et al., 2007). Large relative change in pre calving DMI have been linked to mobilization of adipose tissue predisposing cows to metabolic disorders (Drackley et al., 2005; Grummer et al., 2004). Prevention of overconsumption of energy during the dry period is challenging due to many factors including; dry matter intake in dry cows, improvements in quality and digestibility of forages, and limitations on exercise space available for dry cows.

In this symposium paper we summarize results from four studies aiming to understand the impact of prepartum nutrition on postpartum performance, energy balance and lipid metabolism. Factors investigated include; forage digestibility in prepartum diets (wheat straw vs. grass hay), ad libitum vs. restricted feeding, prepartum carbohydrate (sugar vs. starch) supplementation, effects of length of time feeding negative DCAD diets prepartum, and factors regulating colostrum yield. We hope you enjoy our findings and welcome comments and suggestions to improve upon these studies.

Effects of Feeding Wheat Straw or Orchardgrass at Ad Libitum or Restricted Intake During the Dry Period on Postpartum Performance and Lipid Metabolism

Background

Maintaining DMI in periparturient dairy cattle is important to minimize disruption in energy balance which is known to affect lipid mobilization and performance of dairy cattle after parturition. Minimizing the extent and duration of negative energy balance will help reduce lipid mobilization which is linked to liver lipid accumulation (Hammon et al., 2009; McCarthy et al., 2010), and impaired immune function (Wathes et al., 2009). The concept of prepartum limit feeding has received some interest from researchers. Grum et al. (1996) was the first to report lower energy intake prepartum (with lower DMI due to fat supplementation) was associated with lower liver lipid accumulation without significant detriment to milk production. Subsequently, Douglas, (2006) limit fed cow's prepartum and observed higher DMI and NE_L intake during the first 21 d postpartum compared with ad libitum fed cows. The authors concluded that the amount of prepartum energy intake had an impact on metabolism as lower prepartum energy intake resulted in improvements in key metabolic indicators. Other researchers have demonstrated that limit feeding prepartum to maintain consistent energy balance (Kunz et al., 1985 and Holcomb et al., 2001) or slightly negative energy balance prepartum (Holtenius et al., 2003) resulted in higher postpartum DMI. More recently Dann et al, (2006) demonstrated that cows with lower energy balance (either limit fed or by using wheat straw to dilute the dietary energy density) during the far-off dry period had higher postpartum DMI and energy balance and lower serum non-esterified fatty acids (**NEFA**) and beta-hydroxy butyrate acid (**BHBA**) during the first ten days in milk (**DIM**).

Reasons for improvements in postpartum DMI with limiting energy intake prepartum by restricted feeding remain unclear. Limit fed cows have lower energy intake and potentially are at lower risk for excessive lipid mobilization compared with ad libitum fed cows that often consume energy in excess of requirements (Dann et al., 2006; Winkelman et al., 2008). Limit feeding also prevents body condition score gain during the dry period (Dann et al., 2006), reduces feed costs, and reduces the amount of nutrients excreted into the environment (Hoffman et al., 2007; Zanton and Heinrichs, 2007). Perhaps restricted fed cows have less rumen fill and a greater appetite drive immediately postpartum compared to ad libitum fed cows. The impact of prepartum rumen fill on feed intake would likely only be transient unless limit feeding has carryover effects on postpartum feeding behavior. The digestibility of limit fed diets and mean ruminal retention time are also likely important factors contributing to DMI in the first week postpartum. Sheep fed in restricted amounts spent more time ruminating per gram of DMI (Galvani et al., 2010) and cattle fed in restricted amounts increased chewing rate when eating and ruminating (Dias et al., 2011).

In addition to restricted feeding we wanted to compare the impact of feeding two forages, wheat straw (**WS**) or orchard grass hay (**OG**) that varied greatly in physical and chemical properties to determine the impact of forage type on periparturient performance. Wheat straw tends to be lower in K than grasses which accumulate K within plant tissue. Minerals from forages are thought to be readily digestible and contribute to the dietary cation-anion difference (**DCAD**). Positive DCAD increases the risk for hypocalcemia and related periparturient disorders (Lean et al., 2006). Additionally, the rate of digestion is also likely an important factor in selection of forages for dry cow diets. Wheat straw has a slower ruminal disappearance rate compared with high quality grass hay resulting in greater rumen fill that maintains a more stable rumen fiber mat reducing the risk for displaced abomasum after freshening (Douglas et al., 2006; Janovick et al., 2011), but perhaps also limits feed intake the first days after parturition. The amount and rate of digestion of NDF on the periparturient dairy cow is unknown. The rate and extent of NDF digestion impacts ruminants by altering DMI, microbial ecology, volatile fatty acid production, rumination behavior and influencing the rate of passage through the GI tract.

The objectives of this study were to determine if limit feeding during the dry period prevented the drop in intake at parturtition and to determine if forage source alters prepartum energy intake postpartum performance and metabolism. We hypothesized that limit feeding would result in more consistent DMI through parturition and that grass hay would result greater prepartum energy intake compared to wheat straw.

Materials and Methods

Holstein and Holstein crosses with Jersey, Montbeliard, and Swedish Red dairy cattle (N = 40) entering second or later lactation were selected from the University of Minnesota Dairy Teaching and Research Center. At day of dry-off (45 d prior to expected calving) cows were assigned to one of four treatments; 1) wheat straw ad libitum (**AWS**), 2) orchard grass hay ad libitum (**AOG**), 3) wheat straw restricted (**RWS**), 4) orchard grass restricted (**ROG**). Restricted diets were fed at 70% of NRC, 2001 predicted DMI for dry cows. Dietary treatments are described in Table 1. Prepartum diets fed A were formulated for 13.6 kg/d of DMI and R were formulated for 9.5 kg/d of DMI. To ensure nutrient requirements were met for R, diets were formulated to supply greater than 100% of nutrient requirements for multiparous dry cows averaging 635 kg at 270 d gestation when fed ad libitum. All nutrient requirements were met except for metabolizable protein which was calculated to be 106 ± 6.0 g/d less than required for cows fed R however; requirements for amino acids lysine and methionine were met. Wheat straw and grass hay were chopped in a vertical mixer to reduce particle size to a uniform consistency between forages. Cows were fed a common lactation diet after calving and measurements were made through 30 d postpartum.

Intake and Digestibility

As planned, prepartum DMI was higher ($P < 0.0001$) for A vs. R (Table 2). Ad libitum fed cows ate 2.4 ± 0.1% of their body weight as DM during the dry period and R fed cows consumed 1.4 ± 0.1% of BW in DM. Weekly DMI decreased ($P < 0.0001$) for all treatments one week prior to calving. Prepartum energy intake, energy balance and energy balance expressed as a percent of requirements were higher ($P < 0.0004$) for A vs. R (Table 2). Prepartum total tract DM digestibility was higher ($P < 0.003$) for OG vs. WS and OM digestibility tended ($P = 0.07$) to be higher for OG vs. WS diets (Table 2). Intake of WS averaged 4.7 and 2.8 kg/d for cows fed AWS and RWS and intake of OG averaged 4.6 and 2.9 kg /d for cows fed AOG and ROG. Intake of NDF was similar between forages but greater (P < 0.001) for A vs. R. Amount of NDFd was higher ($P < 0.0012$) for OG than WS and was higher ($P < 0.0007$) for A vs. R. Additionally, the amount of apparent total tract NDFd was greater for OG treatments and was nearly twice as high for A vs. R. Despite being fed diets varying in forage and amount, cows fed AWS and ROG had nearly identical amounts (2.0 kg/d) of apparent NDF digested. Prepartum BW and BCS and change in BW and BCS during the prepartum period were unaffected by treatments (Table 2).

Postpartum DMI during the first thirty days of lactation was higher ($P < 0.046$) for OG vs. WS fed cows' prepartum (Table 2). Postpartum energy intake was similar across treatments. Postpartum energy balance of cow's fed A tended ($P = 0.08$) to be higher than those fed R. Postpartum energy balance was negative for all treatments through 30 DIM, but least for cows fed AOG prepartum. During the first thirty days postpartum cows lost a similar amount of body weight (35.5 ± 28.4 kg) and BCS (0.29 ± 0.1).

One week prior to calving there was no effect of forage type on DMI or energy balance and cows fed A continued to consume greater amounts of energy compared with R (Table 3). During the week prior to calving, energy balance of cows fed RWS and ROG became negative. Calf birth body weight was not different among treatments and averaged 44 ± 1.3 kg.

During the first week postpartum, DMI expressed as a percentage of BW was higher ($P < 0.0131$) for A vs. R fed cows (Table 3). Energy balance decreased for all treatments after calving and was lower for R than for A. Cows fed A were in less negative energy balance than R due to greater DMI. Milk yield during the first week of lactation was higher ($P < 0.001$) for OG vs. WS fed cows but 3.5% FCM yield was unaffected by treatments. Milk fat and protein were unaffected by treatment during the first week of lactation and fat:protein averaged 1.3 ± 0.1 and was also similar among treatments. Lactose tended ($P = 0.07$) to be highest for OG vs. WS.

Milk and milk component yield for the first 30 DIM are described in Table 4. Milk yield averaged 39.3 ± 2.2 kg/d and was similar among treatments. There was a forage × amount interaction ($P < 0.04$) as yield of 3.5% FCM was higher for ROG than AOG and RWS but similar for AWS. Dairy efficiency, and proportions of fat, protein, and lactose in milk, fat:protein protein yield, milk urea nitrogen concentration, and somatic cell count were all similar among treatments. There was a forage × amount interaction as ROG fed cows had a higher milk fat yield than cows fed AWS, AOG and RWS.

Prepartum circulating NEFA were similar among forage types and feeding amount and increased ($P < 0.0001$) as cows approached parturition (Table 5). Serum BHBA increased as cows approached calving but were similar among treatments. Prepartum liver total lipid was higher ($P < 0.03$) on d -30 and -14 for R compared with A. Prepartum liver triglycerides were similar among treatments. Serum NEFA were higher postpartum than prepartum but were not affected by treatment. Postpartum circulating NEFA peaked on day 3 and decreased thereafter. There was an interaction of forage × amount ($P < 0.05$) as serum from AWS fed cows had the highest postpartum BHBA compared to the other treatments. Postpartum liver lipid and triglyceride concentration peaked on d 14 but was unaffected by treatment.

Summary 1

In summary, feeding high quality OG prepartum resulted in higher prepartum DM and NDF digestibility, higher postpartum DMI and higher postpartum energy intake compared with diets containing WS. Postpartum energy balance tended to be higher for A vs. R. Milk yield for wk 1 was greater for OG vs. WS but yield of FCM was similar among forage types. During the first month of lactation cows fed ROG produced the greatest amount of milk and had the highest fat yield. Serum BHBA was highest for WSA.

Table 1. Ingredient and nutrient composition (n = 5) of dietary treatments for cows fed TMR with 30% wheat straw in ad libitum (AWS) or restricted (WSR) amounts or 30% orchard grass hay in ad libitum (AOG) or restricted (ROG) amounts prepartum.

	Treatment[1]		
	AWS/RWS	AOG/ROG	SEM
Ingredient			
Wheat straw, chopped, % DM	30.0	0.0	
Orchard grass, chopped, % DM	0.0	30.0	
Corn silage, processed, % DM	20.7	46.2	
Alfalfa hay, chopped, % DM	10.0	10.0	
Shelled corn, ground, % DM	18.2	0.0	
Soybean meal, 48%, % DM	16.8	9.5	
Vitamin/mineral mix[2], % DM	4.3	4.3	
Nutrient Composition			
CP, %	14.7	14.2	0.5
NE_L, Mcal/kg	1.51	1.50	<0.1
NDF, %	37.0	41.0	<0.1
Sugar, %	3.8	3.6	0.6
Starch, %	14.6	7.0	<0.1
Fat, %	2.2	2.5	0.2
Ash, %	6.9	8.1	<0.1
Calcium, %	0.54	0.62	<0.1
Phosphorous, %	0.35	0.37	<0.1
Magnesium, %	0.24	0.29	<0.1
Potassium, %	1.4	1.8	<0.1
DCAD1 (meq/100g)[3]	21.0	30.2	2.0
DCAD2 (meq/100g)[4]	21.6	31.7	2.0

[1] AWS = ad libitum fed TMR with 30% wheat straw; AOG = ad libitum fed TMR with 30% grass hay; RWS = restricted to 70% of predicted ad libitum DMI of TMR with 30% wheat straw ROG = restricted to 70% of predicted ad libitum DMI of TMR with 30% grass hay.

[2] DM = 66.0%, CP = 18.2%, fat = 7.3%, Ca = 4.5%, P = 2.1%, Mg = 0.6%, Cl = 6.5%, K = 2.9, Na = 3.7%, S = 0.6%, Co = 16.5 mg/kg, Cu = 206.1 mg/kg, I = 27.3 mg/kg, Fe = 1317.7 mg/kg, Mn = 901.5 mg/kg, Se = 9.3 mg/kg, Zn = 1545.5 mg/kg.

[3] DCAD1: (Na + K) – (Cl + S).

[4] DCAD2: [(Na + K + 0.38Ca + 0.30Mg) − (Cl + 0.60S + 0.50P)] (Horst and Goff, 1997).

Table 2. Effects of prepartum diet varying in forage type (wheat straw vs. grass hay) and feeding amount (ad libitum vs. restricted) on prepartum (-42 to calving) intake, energy balance, diet digestibility, body weight and body condition score and postpartum (calving to 30 DIM) intake, energy balance, body weight and body condition score.

	Treatment[1]					*P*-Value			
	AWS	AOG	RWS	ROG	SEM	Forage	Amount	F × A[2]	Week
					Prepartum				
DMI, kg/d	15.8	15.5	9.4	9.6	1.0	0.97	<0.0001	0.78	0.06
DMI, % of BW	2.4	2.3	1.4	1.4	0.1	0.87	0.09	0.49	0.43
Energy intake, Mcal/d	24.7	23.7	13.9	15.1	1.7	0.94	<0.0001	0.50	0.53
Energy balance, Mcal/d	+10.6	+9.5	-0.4	+0.9	1.7	0.95	<0.0001	0.41	0.13
Energy balance, % reqt.	175.9	165.2	97.4	107.2	11.7	0.97	<0.0001	0.33	0.08
DM digestibility, %	56.1	68.2	52.4	61.2	3.2	<0.003	0.10	0.61	---
OM digestibility, %	59.1	67.5	55.5	59.6	3.4	0.07	0.10	0.53	---
NDFI, kg/d	6.3	6.2	3.5	4.1	0.5	0.63	<0.001	0.44	<0.001
NDF digestibility,%	33.5	53.6	30.6	49.0	4.0	<0.0036	0.316	0.82	---
NDF digested, kg/d	2.0	3.5	1.1	1.9	0.3	<0.0012	<0.0007	0.28	---
BW, kg	679.9	680.6	668.5	678.4	34.4	0.96	0.90	0.84	<0.0001
BW change, kg	+43.3	+30.0	+35.3	+52.7	8.5	0.79	0.35	0.06	---
BCS	3.48	3.45	3.52	3.50	0.15	0.82	0.88	0.99	<0.0001
BCS change	+0.22	+0.34	+0.30	+0.59	0.15	0.14	0.27	0.56	---
					Postpartum				
DMI, kg/d	17.6	22.2	18.4	19.6	1.5	<0.04	0.52	0.25	< 0.0001
DMI, % of BW	3.0	3.6	3.1	3.2	0.2	0.14	0.43	0.24	< 0.0001
Energy Intake, Mcal/d	32.0	36.3	30.5	31.7	3.6	0.42	0.37	0.64	< 0.0001
Energy Balance, Mcal/d	-7.2	-2.0	-8.5	-11.4	3.2	0.70	0.08	0.19	0.02
Energy balance, % reqt.	80.2	96.6	81.0	74.6	8.1	0.49	0.16	0.13	0.09
BW, kg	617.6	639.2	618.3	645.1	28.4	0.14	0.43	0.24	<0.0001
BW change, kg	-41.6	-26.5	-38.6	-35.2	12.9	0.26	0.89	0.40	---
BCS	3.1	3.2	3.1	3.2	0.14	0.57	0.99	0.73	<0.0001
BCS change	-0.29	-0.23	-0.25	-0.38	0.11	0.90	0.78	0.26	---

[1] WS = ad libitum fed TMR with 30% wheat straw; AOG = ad libitum fed TMR with 30% grass hay; RWS = restricted to 70% of predicted ad libitum DMI of TMR with 30% wheat straw ROG = restricted to 70% of predicted ad libitum DMI of TMR with 30% grass hay.

[2] F × A interaction of forage type and amount fed.

[a,b] Different subscripts $P < 0.05$.

Table 3. Effects of prepartum diet varying in forage type (wheat straw vs. grass hay) and feeding amount (ad libitum vs. restricted) on wk 1 prepartum intake, energy balance and wk 1 postpartum intake, energy balance, milk and milk component yield.

	Treatment[1]					*P*-Value		
Variable	AWS	AOG	RWS	ROG	SEM	Forage	Amount	F × A
			Week 1 Prepartum					
DMI, kg/d	15.4	16.4	8.2	9.1	1.2	0.43	<0.0001	0.95
DMI, % of BW	2.2	2.3	1.3	1.3	0.2	0.79	<0.0001	0.86
Energy intake, Mcal/d	24.0	24.2	12.6	13.4	2.3	0.83	<0.0001	0.84
Energy balance, Mcal/d	9.5	9.5	-2.1	-1.3	22	0.72	<0.0001	0.96
Energy balance, % of rqt.	166.3	163.0	85.5	91.5	15.3	0.92	<0.0001	0.74
Calf weight, kg	43.5	44.8	43.3	44.5	1.3	0.33	0.83	0.99
			Week 1 Postpartum					
DMI, kg/d	17.3	18.5	15.2	15.0	1.9	0.79	0.12	0.70
DMI, % of BW	2.5	2.7	2.3	2.2	0.4	0.34	<0.0131	0.92
Energy intake, Mcal/d	32.8	29.6	24.3	24.0	4.8	0.69	0.12	0.75
Energy balance, Mcal/d	-5.0	-5.5	-10.8	-15.5	4.7	0.57	0.08	0.63
Energy balance, % of rqt.	85.9	83.9	78.6	60.7	12.9	0.41	0.21	0.51
Milk yield, kg	29.4	32.5	25.7	33.5	2.1	<0.01	0.51	0.24
3.5% FCM, kg/d	40.4	39.2	36.9	39.6	3.2	0.82	0.61	0.54
True protein, %	4.1	4.1	4.1	4.2	0.2	0.71	0.79	0.92
Fat, %	5.8	5.6	5.1	5.1	0.4	0.11	0.84	0.74
Fat:protein	1.5	1.3	1.4	1.2	0.1	0.10	0.65	0.77
Lactose, %	4.4	4.7	4.6	4.6	0.1	0.07	0.87	0.15

[1] AWS = ad libitum fed TMR with 30% wheat straw; AOG = ad libitum fed TMR with 30% grass hay; RWS = restricted to 70% of predicted ad libitum DMI of TMR with 30% wheat straw ROG = restricted to 70% of predicted ad libitum DMI of TMR with 30% grass hay.

Table 4. Effects of prepartum diet varying in forage type (wheat straw vs. grass hay) and feeding amount (ad libitum vs. restricted) on milk, milk composition, component yield and dairy efficiency during the first thirty days in milk.

	Treatment[1]					*P*-Value			
Variable	AWS	AOG	RWS	ROG	SEM	Forage	Amount	F×A	Week
Milk yield, kg/d	39.2	38.9	36.7	42.6	2.3	0.20	0.80	0.16	<0.0001
3.5% FCM, kg/d	45.5[ab]	44.0[a]	42.7[a]	50.5[b]	2.3	0.15	0.40	0.04	<0.0001
Dairy efficiency	2.5	1.8	2.0	2.2	0.3	0.29	0.87	0.10	0.24
Fat, kg/d	1.7[a]	1.7[a]	1.6[a]	2.0[b]	0.1	0.20	0.26	0.03	0.09
True protein, kg/d	1.3	1.3	1.2	1.4	0.1	0.13	0.73	0.13	<0.0001
Lactose, %	4.7	4.7	4.8	4.8	<0.1	0.12	0.79	0.89	<0.0001

[1] AWS = ad libitum fed TMR with 30% wheat straw; AOG = ad libitum fed TMR with 30% grass hay; RWS = restricted to 70% of predicted ad libitum DMI of TMR with 30% wheat straw ROG = restricted to 70% of predicted ad libitum DMI of TMR with 30% grass hay.

[a,b] Different subscripts $P < 0.05$.

Table 5. Effects of prepartum diet varying in forage type (wheat straw vs. grass hay) and feeding amount (ad libitum vs. restricted) on prepartum and postpartum concentrations of non-esterified fatty acids (NEFA), beta-hydroxy-butyrate (BHBA) and liver lipids.

	Treatment[1]					*P*-Value			
Variable	AWS	AOG	RWS	ROG	SEM	Forage	Amount	F × A	Day
				Prepartum					
NEFA, µEq/L	217.7	142.9	199.2	192.8	29.9	0.15	0.56	0.23	<0.0001
BHBA, mmol/L	550.0	534.4	446.0	497.0	51.1	0.73	0.17	0.51	0.007
Total lipid, %	4.9	4.7	7.1	6.0	0.9	0.37	0.03	0.54	0.49
Triglyceride, %	0.18	0.18	0.23	0.40	0.16	0.56	0.37	0.55	0.89
				Postpartum					
NEFA, µEq/L	365.2	366.3	366.3	388.0	49.3	0.66	0.94	0.68	<0.0001
BHBA, mmol/L	1162.0[a]	642.0[b]	716.3[b]	986.0[b]	211.4	0.50	0.79	0.04	0.97
Total lipid, %	8.5	7.7	8.5	7.8	1.1	0.98	0.49	0.94	0.82
Triglyceride, %	3.2	2.6	2.0	1.9	0.9	0.72	0.26	0.75	0.05

[1] AWS = ad libitum fed TMR with 30% wheat straw; AOG = ad libitum fed TMR with 30% grass hay; RWS = restricted to 70% of predicted ad libitum DMI of TMR with 30% wheat straw ROG = restricted to 70% of predicted ad libitum DMI of TMR with 30% grass hay.

[a,b] Different subscripts $P < 0.05$.

Effects of Prepartum Controlled Energy Wheat Straw and Grass Hay Diets Supplemented With Starch or Sugar on Periparturient Dairy Cow Performance and Lipid Metabolism

Previous research (Litherland et al., 2010 abstr.) showed dry cows fed diets containing 30 percent high quality chopped orchard grass hay produced more milk during the first wk and had higher DMI during the first month postpartum than cows fed diets containing 30 percent chopped wheat straw. Can a similar increase in milk yield be achieved with lower quality grass hay that is more representative of that fed to dry cows?

Few studies have explored supplemental sugar for dry cows. Ordway et al. (2002) replaced ground corn with 2.7% dry sucrose in diets for the last thirty days prepartum and did not observe improvement in prepartum or postpartum performance; however the control and treatment diets both contained 4.2% molasses. Miller et al. (2005) replaced 3.2% corn grain in the far-off diet and 3.3% in the close-up diet with cane molasses and reported that molasses-fed cows tended to have higher DMI during the close-up period, ate 7% more DM in the first month of lactation and milk yield tended to be higher. Similarly, Miller et al. (2007) fed cane molasses at 3.3% of far-off diet, and 3.6% of close-up diet and reported cows receiving molasses during the dry period had higher DMI during the close-up period and tended to have greater postpartum DMI, and had greater milk production. Maintaining DMI prior to calving with supplemental liquid molasses would prevent the decreases in energy intake resulting in improved periparturient performance. Sucrose and cane molasses supplementation to lactating cows increased DMI (Broderick and Radloff, 2004; Broderick et al., 2008; Penner and Oba, 2009). Sugar supplementation from cane molasses or sucrose has been identified as a method of increasing DMI through multiple mechanisms including; increased fiber digestion and diet palatability, increased rumen pH, and reduced selective consumption of diet particles. Dry matter intake response to sugar supplementation has been variable and is likely diet dependent. Nombekela and Murphy (1995) supplemented 1.5% sucrose and noted a transient increase in DMI for the first 2 wk postpartum, and less variation in 3.5% FCM production for the first 12 wk of lactation compared to control.

Selective consumption (sorting) against low energy density forage particles used to dilute energy density and selective consumption of higher energy dense particles would result in greater energy intake than intended in the diet as formulated. Dry cows are effective sorters against long particles, and for short and fine particles (Hosseinkhani et al., 2008). Using a cane molasses-based liquid feed within a dry cow TMR may offer a novel approach to deliver nutrients and diet conditioning while addressing ration physical concerns of separation and sorting.

Objectives of this study were to compare starch vs. molasses-based liquid feed supplementation in dry cow TMR's containing either 30% chopped wheat straw or 30% low quality chopped grass hay. We hypothesized that supplementation of periparturient cows with molasses-based liquid feed would increase DMI prepartum with wheat straw preventing consumption of energy in excess of requirements. Additionally we hypothesized that molasses-based liquid feed would reduce diet sorting and increase pre-and postpartum nutrient intake compared with starch supplementation. Prepartum treatments (Table 6) included: 1) wheat straw (**WS**) prepartum + corn pre and post partum (**WSStarch**), 2) WS prepartum + molasses-based liquid feed (**LF**) pre and post partum (**WSSugar**), 3) grass hay (**GH**) prepartum + corn pre and post partum (**GHStarch**), 4) GH prepartum + LF pre and post partum (**GHSugar**).

Prepartum DM and Nutrient Intake

There were no effects of forage or supplement on prepartum DMI (Table 7). As a percent of body weight, DMI was not affected by prepartum forage or supplement and averaged 2.0 ± 0.1 % (Table 7). Prepartum DMI expressed as a % of BW did not decrease as calving approached. There was an interaction of forage × week on week -4 and -3 as GH had higher DMI as a % of BW than WS.

Previous research with cane molasses fed at 3.3% of far-off and 3.6% of close-up dry cow diets resulted in increased DMI during the close-up period (Miller et al., 2007). Prepartum intake of NE_L was higher (*P* = 0.05) for GH compared with WS. Energy balance tended (*P* = 0.06) to be lower for WS vs. GH but was unaffected by supplement. Energy balance expressed as a % of requirements indicated cows fed WS tended (*P* = 0.08) to be in less positive energy balance (137.1%) than cows fed GH (155.6 ± 11.3%). Moderating energy intake is one of the primary goals of moderate energy high NDF prepartum diets. Calculated prepartum starch intake was higher (*P* < 0.02) for Starch compared with Sugar supplemented cows. Additionally, calculated Sugar intake was higher (*P* < 0.00001) for Sugar vs. Starch and sugar intake was also higher (P < 0.0001) for GH vs. WS. Calculated CP intake was higher (*P* = 0.01) for GH vs. WS. Prepartum OM and NDF intake were similar among treatments. Intake of ADF tended (*P* = 0.08) to be higher for WS vs. GH.

Prepartum Apparent Total Tract Nutrient Digestibility, Body Weight and Body Condition

Amounts of DMI on wk -3 during the sampling period for diet digestibility were similar among treatments (Table 7). Fecal DM was higher (*P* < 0.008) for Sugar versus Starch but was unaffected by forage source. Prepartum digestibility of DM and OM and amount of DMd and Omd was not affected by forage source but was greater (*P* < 0.03) and OM digestibility tended (*P* = 0.08) to be greater for Starch compared with Sugar. Surprisingly, digestibility of NDF was higher (*P* < 0.02) for WS vs. GH. Higher NDFd for WS vs. GH could be due to the combination of numerically lower DMI for WS vs. GH, greater sorting against long particles in the WS diets and 4.4% greater NDF concentration of GH diets. Similar to results from this study, Colucci et al., 1982, varied NDF content in diets fed to dry cows and observed a decrease in NDFd similar to that observed in this study. Amount of NDFd per cow was similar among forages but tended (*P* = 0.06) to be lower for Sugar vs. Starch. Prepartum body weight was not different among treatments and increased (*P* < 0.05) as parturition approached; however, Sugar increased (*P* < 0.04) body condition score but the increase of 0.1 to 0.2 BCS is not likely biologically significant.

Postpartum DMI, Body Weight and Body Condition

Postpartum DMI was not affected by forage source but was higher (*P* < 0.008) for Starch vs. Sugar, however, DMI as a percentage of body weight was not different among forages (*P* = 0.33) or supplements (*P* = 0.26) (Table 8). DMI increased (*P* < 0.0001) with increasing days in milk. Previous work with sugar supplementation in lactating cows has often shown an increase in DMI (Broderick and Radloff, 2004; Broderick et al. 2008; Firkins et al., 2008; Penner and Oba, 2009). Postpartum DMI and DMI as a % of BW for this trial were comparable to those observed in previous studies feeding MEHF diets prepartum (Dann et al., 2006; Janovick and Drackley, 2010). Penner and Oba (2009) fed low (4.7%) or high (8.4%) sugar diets to dairy cows after calving and reported a 1.1 kg increase in DMI for cows fed the high sugar diet. Results from this study and that by Penner and Oba are not directly comparable because of differences in the amount of sugar supplemented and differences in nutrient composition of the diet.

Due to higher DMI, calculated NE_L intake and postpartum energy balance was higher (*P* < 0.01) for Starch vs. Sugar. Postpartum energy balance decreased until 3 wk postpartum and then increased through wk 6. Postpartum energy balance remained negative through fifty-six DIM. Energy balance expressed as a % of requirements averaged 90.0 % for Starch vs. 79.8 ± 4.2% for Sugar during the postpartum period (Table 8). Previous work demonstrated that energy balance was not different between control and sucrose- supplemented cows; however, energy intake was greater and energy output tended to be higher in sucrose-supplemented cows (Penner and Oba, 2009). As designed, calculated starch intake postpartum was higher (*P* < 0.01) for Starch vs. Sugar and calculated postpartum sugar intake was higher (*P* < 0.0006) for Sugar vs. Starch. Due to lower DMI, postpartum intake of CP, OM, NDF, and ADF were all lower for Sugar vs. Starch supplemented cows. Despite differences in energy balance, treatment averages for postpartum body weight were similar but postpartum BCS was higher ($P < 0.04$) for Sugar vs. Starch. Postpartum body weight and BCS change were similar among treatments.

Milk and Milk Component Yield and Dairy Efficiency

Milk yield tended ($P = 0.07$) to be higher for WS vs. GH but was not affected by supplement ($P = 0.72$), additionally, yield of 3.5% FCM were similar among treatments (Table 9). Penner and Oba, (2009) observed a 1.4 kg increase in milk yield, and tendency for improved milk fat yield with sucrose supplementation for cows from 1 to 28 DIM. Other studies have reported trends for increased milk production with sucrose, molasses, or molasses-based liquid feed supplementation (Broderick and Radloff, 2004; Miller et al., 2005; Miller et al., 2007; Broderick et al., 2008; Firkins et al., 2008). Due to the numerically higher 3.5% FCM yield and numerically lower DMI, dairy efficiency was higher ($P < 0.0008$) for Sugar vs. Starch. Milk fat and protein percentage and yield were similar among treatments. There were no treatment effects on ratio of fat:protein, concentration or yield of lactose or total solids. There was a treatment × week interaction ($P < 0.05$) as MUN decreased for Sugar as lactation progressed. Broderick and Radloff, (2004) reported a reduction in MUN when cane molasses was fed at 3 to 9% of diet DM. Perhaps sugar supplementation improves efficiency of ruminal N capture, or reduces microbial protein yield through increased VFA production.

Prepartum Liver Total Lipid, Triglyceride, Glycogen, and Serum NEFA and BHBA

Biopsies of liver on d -14 prepartum revealed no differences in total lipid or glycogen however; concentration of liver triglyceride tended ($P = 0.06$) to be greater for Sugar vs. Starch (Table 10). Ratio of prepartum liver triglyceride to glycogen was similar among treatments. Concentration of prepartum serum NEFA was greater ($P < 0.0024$) for Sugar vs. Starch and serum concentration of BHBA on d -7 tended ($P = 0.07$) to be greater for Sugar vs. Starch (Table 10). Liver composition values are comparable to those reported by Dann et al. (2006) and Janovick and Drackley (2010).

Postpartum Liver Total Lipid, Tryiglyceride, Glycogen and Serum NEFA and BHBA

Postpartum concentration of total lipids and triglycerides in biopsies of liver tended ($P = 0.09$) to be greater for Sugar vs. Starch (Table 10). The concentration of triglycerides in biopsies of liver on d 7, 14 and 28 postpartum peaked on d 14 (Figure 6). Postpartum liver glycogen concentration was higher ($P < 0.0025$) for cows fed WS vs. GH and tended ($P = 0.09$) to be higher for Starch vs. Sugar. Ratio of liver triglyceride to glycogen tended ($P = 0.06$) to be higher for GH vs. WS, but was lower than ketotic threshold. Postpartum serum NEFA was not different between treatments. Postpartum serum NEFA peaked on d 7 and declined thereafter and was higher ($P < 0.01$) for GH vs. WS but similar among supplements. Serum BHBA however, was ($P = 0.05$) greater for Sugar vs. Starch. Postpartum liver composition and circulating NEFA values are consistent with lower DMI observed for Sugar. Sucrose supplementation increased both NEFA and BHBA concentration in postpartum cows (Penner and Oba, 2009).

Calf Birth Weight and Colostrum Yield

Calf birth weight averaged 47.9 ± 3.0 kg and was similar among treatments. An important goal of the dry cow program is production of sufficient amounts of quality colostrum to ensure passive transfer of IgG to the calf. Colostrum yield below 5.0 kg is considered insufficient to provide the calves on this trial with ca. 10% of their birth body weight in colostrum. Among treatments, 13.3% of cows failed to produce greater than 5.0 kg of colostrum (data not shown).

Selective Particle Consumption

One of the objectives of this study was to determine if LF reduces sorting (selective particle consumption) in a TMR. Given the differences in ingredients (WS vs. GH), it is not surprising that particle size of the TMR's were different among treatments (Table 11). In general, GH TMR's had more particles > 19.0 mm, and the WS diets had more particles 19.0 to 8.0 mm in length and 8.0 to 1.2 mm in length. In addition, the adherence properties of LF may have agglomerated some of the fine particles to larger ones, reducing the fine material in the particle distribution.

During the prepartum period all cows selected against particles > 19.0 mm in length and selected for particles < 1.18 mm in length (Table 10). Compared with GH, cows fed WS sorted ($P < 0.05$) against particles >19.0mm in length. Additionally, cows fed WS tended ($P = 0.06$) to sort for particles with a length of 8.0 to 1.18mm in length. There was no effect of supplement on selective consumption of particles.

Summary 2

Prepartum forage and supplement had minimal effects on prepartum intake, lipid metabolism, diet digestibility and selective particle consumption. A single stage dry cow TMR containing 30% DM as chopped wheat straw or grass hay maintained DMI and energy balance through calving. Prepartum Sugar supplementation decreased DM digestibility and increased liver triglycerides and circulating NEFA and tended to increase BHBA. Sugar decreased postpartum DMI and energy balance but not milk or 3.5% FCM yield resulting in increased dairy efficiency. Prepartum forage did not affect postpartum DMI although milk yield tended to be higher for wheat straw vs. grass hay. Additionally, compared with grass, wheat straw resulted in lower postpartum NEFA, higher liver glycogen and tended to have a lower triglyceride:glycogen.

Table 6. Nutrient Composition of diets fed during the dry and lactating period (CPM Dairy 3.0.08).

	Prepartum diets[1]				Postpartum diets	
Nutrient, % of DM	WSStarch	WSSugar	GHStarch	GHSugar	Starch	Sugar
CP,% DM	12.5	12.7	13.8	13.9	17.7	17.8
NE_L, Mcal/kg	1.45	1.45	1.56	1.56	1.74	1.76
NDF, % DM	42.2	41.8	37.8	37.4	29.7	29.4
Sugar, % DM	3.6	6.3	5.1	7.9	4.3	5.9
Starch, % DM	20.1	18.7	20.1	18.7	23.2	22.6
EE Total, % DM	2.0	1.9	2.1	2.1	3.7	3.7
Ash, % DM	8.5	8.3	8.0	7.8	8.7	8.6
Ca, % DM	0.67	0.68	0.74	0.75	0.86	0.87
P, % DM	0.24	0.26	0.26	0.28	0.42	0.43
Mg, % DM	0.29	0.29	0.3	0.3	0.33	0.33
K, % DM	1.40	1.41	1.90	1.90	1.45	1.46
Cl, % DM	0.28	0.42	0.25	0.39	0.37	0.45
DCAD1, meq/100g	12.8	11.0	25.4	23.6	27.9	26.8

[1] Diets fed from 42 d prepartum through 56 d postpartum; wheat straw prepartum + corn pre and post partum (WSStarch); wheat straw prepartum + molasses-based liquid feed (LF) pre and post partum (WSSugar); grass hay prepartum + corn per and post partum (GHStarch); GH prepartum + LF pre and post partum (GHSugar).

[2] Formulated amount.

Table 7. Prepartum (week -6 to calving) dry matter intake (DMI), DMI expressed as a % of BW, energy balance, nutrient intake and digestibility and body weight and body condition score for multiparous dairy cows fed wheat straw or grass hay diets prepartum with either starch or sugar supplement both pre- and postpartum.

	Treatments[1]								
	Wheat Straw		Grass Hay			*P*-value			
Variable	Starch	Sugar	Starch	Sugar	SEM	F[2]	S[3]	F × S[4]	Wk
DMI, kg/d	13.4	13.5	14.8	13.6	0.9	0.29	0.29	0.45	0.25
DMI, % of BW	2.0	1.9	2.1	2.0	0.1	0.20	0.34	0.65	0.25
NE_L intake, Mcal/d	20.3	19.5	23.5	21.7	1.4	0.05	0.33	0.71	0.55
EB,[5] Mcal/d	5.4	4.8	8.6	7.1	1.6	0.06	0.45	0.77	0.77
EnB,[6] %	139.3	134.8	161.5	149.6	11.3	0.08	0.42	0.72	0.06
Starch intake,[7] kg/d	2.7	2.5	3.0	2.5	0.2	0.30	0.02	0.46	0.25
Sugar intake,[7] kg/d	0.5	0.8	0.8	1.1	0.1	<0.0001	<0.0001	0.69	0.45
Fecal DM, %	14.3	15.2	14.4	14.6	0.2	0.24	0.008	0.09	---
DMd, %	58.8	57.6	60.8	57.3	1.1	0.44	0.03	0.29	---
OMd, %	62.4	61.5	64.3	61.3	1.1	0.45	0.08	0.34	---
NDFd,%	41.6	40.2	37.1	34.1	2.2	0.02	0.32	0.70	---
DMI,[8] kg/d week -3	13.9	12.4	14.6	13.1	0.9	0.44	0.11	0.98	---
Body weight,[9] kg	701.3	687.1	694.2	717.3	20.9	0.55	0.82	0.33	---
BCS[9]	3.4	3.5	3.4	3.6	<0.1	0.77	0.04	0.52	0.11

[1] Diets fed from 42 d prepartum until calving; wheat straw prepartum + corn (WSStarch); wheat straw prepartum + molasses-based liquid feed (LF) (WSSugar); grass hay prepartum + corn (GHStarch); GH prepartum + LF (GHSugar).
[2] Wheat straw vs. grass hay diets.
[3] Starch vs. sugar supplement.
[4] Interaction of forage type and supplement type.
[5] Energy balance = $NE_l - (NE_M + Ne_P)$.
[6] Percentage of NE_L requirement.
[7] Average daily prepartum nutrient intake.
[8] Feed and fecal samples were collected from week -3 to week -2 relative to expected calving date to determine digestibility using acid insoluble ash as an internal maker.
[9] Measurements collected weekly.

Table 8. Postpartum DMI, DMI % of BW, nutrient intake and body weight and body weight change for multiparous dairy cows fed wheat straw or grass hay diets prepartum with either a starch or sugar supplement both pre and postpartum.

	Treatment[1]					*P*-value			
	Wheat Straw		Grass Hay						
Variable	Starch	Sugar	Starch	Sugar	SEM	F[2]	S[3]	F × S[4]	Wk
DMI, kg/d	21.3	17.7	20.9	19.3	1.0	0.53	0.008	0.54	<0.0001
DMI, % of BW	3.2	3.1	3.4	3.2	0.1	0.33	0.26	0.65	<0.0001
NE_L intake, Mcal/d	37.1	31.2	36.4	32.8	1.9	0.80	0.01	0.43	<0.0001
Energy balance,[5] Mcal/d	-5.2	-8.4	-3.6	-9.3	1.0	0.86	0.01	0.47	<0.0001
Energy balance,[6] % reqt.	88.8	79.9	91.1	79.6	4.2	0.80	0.01	0.76	<0.0001
Starch intake,[7] kg/d	4.8	4.2	4.8	4.4	0.2	0.50	0.01	0.60	<0.0001
Sugar intake,[7] kg/d	0.9	1.1	0.9	1.1	0.1	0.37	0.0006	0.56	<0.0001
Body weight, kg	701.3	687.0	694.2	717.3	20.9	0.55	0.82	0.33	<0.0001
BCS	3.4	3.5	3.4	3.6	0.1	0.78	0.04	0.52	0.11
BW change,[8] kg	53.9	59.9	46.1	63.7	8.6	0.81	0.15	0.47	---
BCS change[9]	0.15	0.22	0.19	0.27	<0.1	0.67	0.35	0.98	---

[1] Diets fed from 42 d prepartum until calving; wheat straw prepartum + corn (WSStarch); wheat straw prepartum + molasses-based liquid feed (LF) (WSSugar); grass hay prepartum + corn (GHStarch); GH prepartum + LF (GHSugar).
[2] Wheat straw vs. grass hay diets.
[3] Starch vs. sugar supplement.
[4] Interaction of forage type and supplement type.
[5] Energy balance = $NE_I - (NE_M + Ne_L)$.
[6] Percentage of NE_L requirement.
[7] Average daily prepartum nutrient intake.
[8] Wk 6 body weight minus wk 1 body weight.
[9] Wk 6 body condition score minus wk 1 body condition score.

Table 9. Milk and 3.5% FCM yield, dairy efficiency, milk component concentration, milk component yield, fat:protein and SCC for multiparous dairy cows fed wheat straw or grass hay diets prepartum with either a starch or sugar supplement both pre and postpartum.

	Treatments[1]								
	Wheat Straw		Grass Hay			*P*-value			
Variable	Starch	Sugar	Starch	Sugar	SEM	F[2]	S[3]	F × S[4]	Wk
Milk, kg/d	42.1	40.7	38.8	39.2	1.4	0.07	0.72	0.49	<0.0001
3.5% FCM[5]	46.1	44.8	44.2	44.3	1.8	0.51	0.75	0.70	<0.0001
Dairy efficiency[6]	2.2	2.6	2.1	2.4	0.1	0.15	<0.0008	0.83	0.0073
Fat, %	4.2	4.3	4.4	4.5	0.2	0.25	0.65	0.85	<0.0001
True protein,%	3.2	3.0	3.2	3.2	0.1	0.31	0.18	0.36	<0.0001
Fat:protein	1.3	1.4	1.4	1.4	<0.1	0.60	0.24	0.60	0.25
Urea N, mg/dL	14.0	14.3	13.3	12.9	0.5	0.04	0.90	0.49	<0.0001

[1] Diets fed from 42 d prepartum until calving; wheat straw prepartum + corn (WSStarch); wheat straw prepartum + molasses-based liquid feed (LF) (WSSugar); grass hay prepartum + corn (GHStarch); GH prepartum + LF (GHSugar).
[2] Wheat straw vs. grass hay diets.
[3] Starch vs. sugar supplement.
[4] Interaction of forage type and supplement type.
[5] 3.5% FCM, Kg/d = (0.4324 x kg of milk) + (16.216 x kg of milk fat).
[6] Dairy efficiency= 3.5% FCM/DMI.

Table 10. Prepartum concentrations of glycogen, total lipids, triacylglycerols in biopsies of liver -14 d and serum concentration of NEFA on d -28, -14 and -7 and BHBA on d -7 for multiparous dairy cows fed wheat straw or grass hay prepartum supplemented with either starch or sugar both pre and postpartum.

	Treatments[1]					*P*-value			
	Wheat Straw		Grass Hay						
	Starch	Sugar	Starch	Sugar	SEM	F[2]	S[3]	F × S[4]	Day
Prepartum									
Total lipid,[5] %	4.4	4.4	4.5	4.5	0.2	0.73	0.91	0.98	---
Triacylglycerol,[5] %	0.31	0.53	0.37	0.60	0.1	0.57	0.06	0.96	---
Glycogen,[5] %	4.2	4.8	4.9	4.3	0.5	0.84	0.97	0.24	---
Triacylglycerol:glycogen	0.16	0.19	0.12	0.24	<0.1	0.85	0.14	0.37	---
NEFA, µEq/L	88.6	176.9	92.1	129.5	20.6	0.27	0.0024	0.20	<0.0001
BHBA, mMol/L	400.0	691.7	658.3	615.4	69.7	0.18	0.07	0.02	---
Postpartum									
Total lipid,[5] %	8.9	9.8	9.2	11.9	1.1	0.24	0.09	0.42	0.025
Triacylglycerol,[5] %	4.7	5.4	4.6	7.0	0.9	0.38	0.09	0.32	<0.0001
Glycogen,[5] %	2.9	2.3	2.0	2.0	0.2	0.0025	0.09	0.14	<0.0001
Triacylglycerol:glycogen	2.1	3.3	3.5	4.9	0.8	0.06	0.10	0.86	0.0007
NEFA, µEq/L	368.6	415.0	466.7	543.2	44.5	0.01	0.16	0.72	<0.0001
BHBA, mMol/L	837.9	1292.4	1026.2	1171.2	161.3	0.82	0.05	0.29	0.45

[1] Diets fed from 42 d prepartum until calving; wheat straw prepartum + corn (WSStarch); wheat straw prepartum + molasses-based liquid feed (LF) (WSSugar); grass hay prepartum + corn (GHStarch); GH prepartum + LF (GHSugar).
[2] Wheat straw vs. grass hay diets.
[3] Starch vs. sugar supplement.
[4] Interaction of forage type and supplement type.
[5] Percent of wet weight.

Table 11. Particle size, dry matter (DM), and calculated selective particle consumption in prepartum diets using a Penn State particle size separator box for multiparous dairy cows fed wheat straw or grass hay diets prepartum with either a starch or sugar supplement both pre and post partum.

	Treatments[1]							
	Wheat Straw		Grass Hay			*P*-value		
Item	Starch	Sugar	Starch	Sugar	SEM	F[2]	S[3]	F × S[4]
Particles retained, % as fed retained								
>19.0 mm	11.4	13.0	20.3	20.3	2.5	0.003	0.75	0.73
19.0 to 8.0 mm	43.6	46.1	39.9	41.8	1.8	0.035	0.20	0.90
8.0 to1.18 mm	33.6	31.0	27.9	27.8	1.2	0.009	0.26	0.28
<1.18 mm	11.3	9.9	11.9	10.0	1.0	0.76	0.13	0.86
TMR DM, %	54.0	56.5	52.8	49.2	0.6	0.03	0.13	0.01
Refusal DM, %	53.4	53.6	52.3	52.8	0.7	0.39	0.74	0.88
[100 × (intake/predicted intake)], as fed retained								
19.0 mm	95.1	89.8	98.5	96.4	2.4	0.03	0.11	0.48
8.0 mm	97.7	97.7	98.1	97.3	0.9	0.98	0.68	0.60
1.18 mm	103.4	104.2	101.2	102.5	1.0	0.06	0.28	0.80
Pan	104.8	107.9	104.5	106.8	2.3	0.75	0.22	0.85

[1] Diets fed from 42 d prepartum until calving; wheat straw prepartum + corn (WSStarch); wheat straw prepartum + molasses-based liquid feed (LF) (WSSugar); grass hay prepartum + corn (GHStarch); GH prepartum + LF (GHSugar).
[2] Wheat straw vs. grass hay diets.
[3] Starch vs. sugar supplement.
[4] Interaction of forage type and supplement type.

Effects of Feeding Moderate-energy High-forage Diets With Reduced DCAD for Twenty-one or Forty-two Days Prepartum on Mineral Homeostasis and Postpartum Performance

Introduction and Objectives

Calcium (Ca) homeostasis is vital for normal function of biological processes in the dairy cow, with hypocalcemia (blood Ca < 8 mg/dL) having detrimental effects on skeletal muscle function, smooth muscle function, including gastrointestinal tract motility and immune function (Daniel, 1983, Hurwitz, 1986, Kimura et al., 2006). The dramatic increase in Ca needs for production of colostrum and the ensuing lactation rapidly depletes the cow's blood Ca pool, leaving the cow susceptible to hypocalcemia and milk fever (blood Ca < 5 mg/dL).

Hypocalcemia most recently has been quantified to clinically affect upwards of 10% of multiparous dairy cows and 50% sub-clinically, depending on lactation number (Reinhardt et al. 2011). Feeding reduced dietary cation-anion difference (DCAD) through supplementation of anionic feeds or selection of low-potassium forages are strategies to prevent hypocalcemia, with 26.7% and 46.9% of producers using these methods, respectively (USDA, 2007). Lowering the DCAD (more anions than cations) of the prepartum diet induces a mild metabolic acidosis, with remodeling of bone responsible for providing elements to negate the systemic pH imbalance (Bushinsky, 2000). This action frees calcium complexed in the bone matrix, making more Ca available at calving while promoting bone Ca resorption. Others have reported increased Ca around calving when supplying anions to reducing DCAD during the close-up period (~ 3 wk prepartum) beyond that achieved by low-K ingredients, although additional effects on production were not observed (Moore et al., 2000, Ramos-Nieves et al., 2009).

Of the many factors that influence DMI, three factors: pen or diet changes, anion source, and prepartum diet have been identified as nutrition and management practices that can increase DMI in the transition dairy cow.

Anionic supplements are typically fed during the close-up period, however, diet changes or moving cows to a close-up pen 3 weeks prior to expected calving may increase feed adaptation time and social stress with the addition and removal of cows (Nordlund, 2006, 2009). As cows reestablish a hierarchy after pen changes, displacements from the feed bunk are increased and DMI can be reduced. Following the "all-in, all-out" strategy for dry cow grouping ensures that herd dynamics will be more stable at calving and drops in DMI due to social stress will be reduced. Can we develop a dry cow feeding strategy that both decreases pen moves and reduces the risk of hypocalcemia?

Extended feeding (> 21 d) of reduced DCAD during the dry period (Block, 1984) and negative DCAD in high forage, low potassium diets (Siciliano-Jones, 2008) has been investigated; however, none have assessed effects of extended reduced DCAD using acidified fermentation products in MEHF diets. Furthermore, this strategy has the ability to allows producers to minimize dry cow pen moves and diet changes, incorporating the "all-in, all-out" management practice to reduce stress received by the cows. Objectives for this experiment were to 1) confirm positive effects on mineral homeostasis seen by reducing DCAD in low-cation prepartum diets, as well as, to 2) determine if feeding anionic fermentation products to reduce DCAD in low-cation MEHF diets for the entire dry period would affect mineral homeostasis, energy metabolism and performance of multiparous cows during the transition period in comparison to traditional 21 d anionic feeding periods.

Results and Discussion

Diet ingredient composition and nutrient profiles are described in Table 12. Crude protein concentrations of the dry cow diets were higher than anticipated. Additional amounts of anions were necessary to maintain a urine pH in the optimal range identified Ca homeostasis. CP amounts of the control diet were adjusted accordingly to keep prepartum diets isonitrogenous.

As designed, prepartum urine pH of 21-ND and 42-ND were significantly lower ($P < 0.01$) compared to CON (Table 13) while being fed the anionic diet. Urine pH for 42-ND averaged 6.4 with CON averaging 8.2 during the dry period. 21-ND had an average urine pH of 6.9 during the dry period with urine pH being 8.2 during wk -5 and 6.5 while receiving the negative DCAD diet for wk -3 through -1.

Dry Matter Intake and Energy Balance

Prepartum DMI was not different ($P = 0.12$) between cows fed anionic diets for 21 or 42 d and were similar to CON ($P = 0.94$) (Table 13). A significant effect of week can be explained by an approximately 2 kg drop in DMI in the week preceding calving. Others feeding acidified fermentation products in MEHF diets containing wheat straw during the dry period have reported mixed effects on prepartum DMI (Oetzel and Barmore, 1993, Vagnoni and Oetzel, 1998, Siciliano-Jones et al., 2008, Ramos-Nieves et al., 2009, Rezac et al., 2010). Data from this study is similar to Siciliano-Jones et al., 2008, feeding a negative DCAD high-fiber diet with wheat straw resulted in no differences in prepartum DMI compared to a positive DCAD control diet. Anionic salts supplemented in addition to acidified fermentation products to reduce a high fiber diet DCAD to -15 mEq/ 100 g DM caused reductions in prepartum DMI (14.4 vs. 15.6 kg/ d) compared to a positive DCAD control diet (Ramos-Nieves et al., 2009). Reduction in prepartum DMI might be explained by supplementation of anionic salts in addition to acidified fermentation products, which can be unpalatable when fed in amounts needed to prevent hypocalcemia (Oetzel and Barmore, 1993). Reduction of prepartum DMI has occurred through sole administering acidified fermentation products (Vagnoni and Oetzel, 1998, Rezac et al., 2010). When depressed prepartum DMI was reported by inclusion of acidified fermentation products, an inclusion rate of > 6% (DM basis) of the diet was supplied by acidified fermentation products (Vagnoni and Oetzel, 1998, Ramos-Nieves et al., 2009). Acidified fermentation products were supplied at 9.3% (DM basis) in this trial with no detrimental effects on prepartum DMI. These data suggest other nutritional or management factors led to decreased prepartum DMI reported by others with acidified fermentation products to reduce diet DCAD.

In the current study, anions were supplemented at 472 mEq/ kg DM in the negative DCAD diet, well above that (300 mEq/ kg DM) reported by Charbonneau et al., 2006 to have potential to reduce prepartum DMI. Postpartum DMI increased (wk = $P < 0.01$) after calving and tended ($P = 0.09$) to be higher for 21-ND and 42-ND compared to CON. 21-ND tended ($P < 0.10$) to have greater postpartum DMI on wk 2, 3, and 4 compared to CON. Prepartum and postpartum EB were not different between 21-ND and 42-ND and were similar to CON (Table 13). Due to the drop in DMI as calving approached, prepartum EB drop from 5.7 to 3.5 Mcal/d (wk = $P < 0.001$) 1 wk prepartum. Postpartum EB was most negative the wk following parturition (-10.5 Mcal/d), increasing to -6.7 Mcal/d by wk 4 postpartum. Analyzing data from one wk prepartum through one wk postpartum showed no differences in DMI among treatments, however, numerically greater postpartum DMI for anionic diets resulted in a tendency ($P = 0.06$) for 21-ND and 42-ND to be in a state of less negative energy balance compared to CON (Table 13).

Body Weight, Body Weight Loss, and Body Condition Score

Prepartum and postpartum means for body weight were similar ($P = 0.88$ and $P = 0.95$) among prepartum treatments (Table 15). Postpartum weight loss through 28 DIM was not different among treatments. Postpartum weight loss was greatest in 42-ND, resulting in 13% and 3% greater losses than CON and 21-ND, respectively. Prepartum BCS was not different comparing anionic diets to CON, but 21-ND tended to have lower prepartum BCS compared to 42-ND (3.1 vs. 3.3, $P = 0.08$). Postpartum BCS was similar between anionic diets and CON, however cows on 42-ND tended ($P = 0.10$) to have greater BCS in contrast to 21-ND.

Milk Production and Components

In our study, 21-ND and 42-ND produced more milk (*P* = 0.01) for the first eight weeks of lactation, on average, than cows receiving the control diet (39.1 kg/d vs. 44.8 kg/d) (Table 16). 21-ND tended to have greater milk for week 1 postpartum, achieving significantly greater production for the remainder of trial. 42-ND was similar to CON for weeks 1 through 3 and tended (*P* < 0.10) to have greater milk than CON weeks 3 through 5. 42-ND produced significantly greater milk for weeks 6 through 8 compared to CON. No differences in milk production (*P* = 0.50) were observed between cows fed anionic diets for 21 or 42 d, indicating that extended negative DCAD feeding did not have detrimental effects on milk yield. When analyzing data from 1 week postpartum only, anionic diets had faster starts (*P* = 0.03) in milk, yielding 31.6 kg/d and 29.8 kg/d for 21-ND and 42-ND in comparison to 26.5 kg/d for CON.

Yield of 3.5% FCM was similar between CON and anionic diets (*P* = 0.37) and averaged 41.0, 44.1 and 43.2 kg/d for CON, 21-ND and 42-ND, respectively. Milk fat yield (kg/d) was similar among all treatments (*P* = 0.87), although a tendency (*P* = 0.10) for 21-ND and 42-ND to have higher protein yield was observed. Milk protein yield for treatments followed a similar trend to milk production, increasing for the first 4 wks postpartum (wk = *P* = <0.01, trt × wk = *P* = 0.29). Cows fed anionic diets for 21 or 42 d prepartum produced significantly more milk lactose than cows on the control diet (*P* = 0.01), and followed similar postpartum increases to those seen in milk production and milk protein yield. Milk lactose yields were 1.7, 2.0 and 1.9 ± 0.1 kg/d for CON, 21-ND and 42-ND, respectively.

Blood Minerals

Diets had no effect on blood mineral concentrations during the prepartum period. Analysis of serum ionized calcium (iCa) and plasma total mineral concentrations can be found in Table 17. Postpartum iCa was not different (*P* = 0.28) for 21-ND and 42-ND compared to CON. All treatments increased at similar rates postpartum, increasing from 4.4 mg/dL at 1 d postpartum to 4.9 mg/dL at d 7 (d = *P* = <0.001). A tendency for anionic diets to have higher (*P*= 0.07) postpartum total Ca (tCa) than CON was present, added, cows receiving anionic supplementation for 42 d had higher (*P* = 0.10) tCa than 21-ND. Total Ca amounts remained low through 24 h postpartum, however, increases in tCa were observed by 72 h postpartum, resulting in a significant time effect (h = *P* = 0.001). All treatments had 90% or greater prevalence of hypocalcemia although 42-ND maintained significantly greater tCa through calving compared to CON and 21-ND. Higher (*P* = 0.07) plasma magnesium (Mg) was observed from 42-ND compared to 21-ND, with CON, 21-ND and 42-ND averaging 1.1, 1.0 and 1.3 ± 0.1 mg/dL, respectively. After calving, Mg increased through 24 h postpartum and decreased thereafter possibly due to greater milk production as Mg inclusion rates in milk are large (0.12 g/ kg) in proportion to their available Mg pool. Higher circulating amounts of phosphorus were observed prepartum (*P* = 0.29) and postpartum (*P* = 0.11) in anionic treatments also indicating increased bone remodeling. Postpartum blood P concentrations followed similar trends to postpartum blood Ca, increasing by 72 h after calving (h = *P* = 0.01) and were highly correlated with tCa (*P* < 0.01, r = 0.75). Tendencies for increased K and Na in anionic diets most likely are due to increases in postpartum DMI.

Serum NEFA and BHBA

Prepartum serum NEFA concentrations were not different among treatments and averaged 228 µEq/L (Table 18). Circulating NEFA concentrations during the postpartum period were similar among prepartum treatments. All treatment's serum NEFA concentrations peaked 7 d (671 µEq/L) after calving and returned to pre-calving concentrations by d 21(405 µEq/L). No trt × d interaction was observed for postpartum NEFA as all treatments followed similar trends. Analysis of postpartum BHBA yielded no significant interactions between anionic diets, however, lower (*P* = 0.12) concentrations of BHBA were observed in 21-ND and 42-ND compared to CON. Anionic diets had decreasing circulating BHBA from d 1 postpartum through d 14, but circulating BHBA levels in CON increased from d 1 postpartum through d 14 (trt × d = P = 0.56), signifying greater liver oxidative capacity in anionic fed cows, or less reliance on adipose stores for energy due to greater postpartum DMI.

Liver Composition

Liver composition during the prepartum period was not affected by prepartum treatment (Table 18). Prepartum liver triglyceride averaged 0.5% during the prepartum period, increasing to 5.5, 3.2, and 4.4% for CON, 21-ND, and 42-ND, respectively, by d 7 after calving. Liver triglyceride percent remained elevated for each treatment through d 14 postpartum. Prepartum liver glycogen percent averaged 5.6% for treatments. Analysis of postpartum glycogen showed a significant (P = 0.04) trt × d effect resulting from higher liver glycogen on d 14 for 42-ND compared to CON and 21-ND.

Summary 3

In conclusion, our results indicate that feeding negative DCAD (-15 mEq/100 g) for 21 or 42 d prepartum utilizing acidified fermentation products positively affected mineral homeostasis, postpartum DMI, and milk production in multiparous cows with no effect on prepartum DMI. Higher postpartum DMI in anionic treatments improved EB resulting in lower BHBA and liver lipid accumulation in 21-ND and 42-ND. Reduced liver lipid accumulation allows for greater hepatic gluconeogenic capacity as the liver can convert glycogen and propionate to glucose. In addition to data from Block, 1984, our results suggest that extending feeding of negative DCAD diets may be needed to consistently achieve greater mineral homeostasis and postpartum performance in multiparous dairy cows.

Table 12. Nutrient composition for prepartum and postpartum diets fed to multiparous dairy cows from 42 d prepartum through 56 d postpartum (CPM Dairy 3.0.08). Feed stuffs comprising diets were collected weekly, composited by month, and analyzed by wet chemistry to determine actual diet nutrient compositions.

	Dry Cow Diets		Lactation Diets
	Negative DCAD	Positive DCAD	CLD[1]
CP, %	16.65	17.33	16.60
NE_L, Mcal/kg	1.47	1.47	1.66
NDF, %	42.54	41.35	31.56
Sugar, %	6.11	6.82	5.57
Starch, %	12.25	11.03	26.12
EE total, %	2.00	1.83	3.97
Ash, %	9.01	8.80	7.42
Calcium, %	0.80	0.82	0.80
Phosphorus, %	0.41	0.40	0.47
Magnesium, %	0.39	0.39	0.32
Potassium, %	1.42	1.51	1.43
Chlorine, %	1.23	0.42	0.49
DCAD1[2], mEq/100g	-15.79	12.34	25.68
DCAD2[3], mEq/100g	-6.94	18.85	28.50

[1] CLD = common lactation diet.
[2] DCAD1 = (mEq/100g) = (Na + K) – (Cl + S).
[3] DCAD2 = (mEq/100g) = (Na + K + 0.38 Ca + 0.30 Mg) – (Cl + 0.6 S + 0.5 P).

Table 13. Least squares means of pre- and postpartum dry matter intake, energy balance and prepartum urine pH from multiparous cows fed prepartum diets with positive DCAD (CON) for 42 d prepartum or negative DCAD (21-ND or 42-ND) for 21 or 42 d prepartum.

	Treatments[1]			P-value	
Variable	CON	21-ND	42-ND	C1[2]	C2[2]
Prepartum					
DMI[3], kg/d	13.7 ± 0.7	14.7 ± 0.9	12.9 ± 0.7	0.94	0.12
DMI[3], %BW	2.0 ± 0.1	2.0 ± 0.2	1.8 ± 0.1	0.72	0.21
EB[4,9], Mcal/d	5.7 ± 1.2	6.0 ± 1.5	3.7 ± 1.2	0.56	0.12
EB[4,10], %Req.	138.5 ± 8.4	139.8 ± 10.6	126.2 ± 8.6	0.61	0.32
Urine pH[5,6]	8.2 ± 0.1	6.9 ± 0.2	6.4 ± 0.1	<0.01	0.01
Postpartum					
DMI[7], kg/d	18.1 ± 0.9	20.8 ± 1.1	19.4 ± 0.9	0.09	0.36
DMI[7], %BW	2.6 ± 0.2	3.0 ± 0.2	2.8 ± 0.2	0.14	0.33
EB[8,9], Mcal/d	-8.8 ± 1.9	-6.8 ± 2.4	-7.4 ± 1.9	0.48	0.84
EB[8,10], %Req.	76.6 ± 4.0	86.4 ± 5.0	81.6 ± 4.0	0.15	0.46

[1] Cows assigned to CON received a prepartum diet with a DCAD value of +12 mEq/ 100 g of DM, 21-ND received a prepartum diet with a DCAD value of -16 mEq/ 100 g of DM for 21 d prepartum and those assigned to 42-ND received a prepartum diet with a DCAD value of -16 mEq/ 100g for 42 d prepartum.
[2] C1: Control vs. 21-ND and 42-ND, C2: 21-ND vs. 42-ND.
[3] DMI = dry matter intake collected from d -42 through d 0 relative to calving.
[4] EB = energy balance calculated from d -42 through d 0 relative to calving.
[5] Sampled at weeks -5, -3, -2 and -1 relative to calving.
[6] Mean value for 21-ND for weeks -3, -2 and -1.
[7] DMI = dry matter intake collected from d 0 through d 28 relative to calving.
[8] EB = energy balance calculated from d 0 through d 28 relative to calving.
[9] EB = energy intake – energy requirements.
[10] EB = energy intake / energy requirements*100.

Table 14. Least squares means of DMI, EB and milk yield from 1 week prepartum through 1 week postpartum from multiparous cows fed prepartum diets with positive DCAD (CON) for 42 d prepartum or negative DCAD (21-ND or 42-ND) for 21 or 42 d prepartum.

	Treatments[1]			P-value	
Variable	CON	21-ND	42-ND	C1[2]	C2[2]
		Week -1			
DMI[3], kg/d	13.2 ± 0.9	13.2 ± 1.1	11.2 ± 0.9	0.41	0.18
DMI[3], %BW	1.9 ± 0.1	1.9 ± 0.2	1.6 ± 0.1	0.40	0.21
EB[3,5], Mcal/d	5.1 ± 1.4	4.1 ± 1.8	1.4 ± 1.5	0.22	0.27
		Week 1			
DMI[4], kg/d	14.3 ± 1.0	16.3 ± 1.2	15.3 ± 1.0	0.23	0.52
DMI[4], %BW	2.1 ± 0.2	2.5 ± 0.2	2.2 ± 0.2	0.38	0.38
EB[4,5], Mcal/d	-13.2 ± 1.7	-8.4 ± 1.9	-10.0 ± 1.5	0.06	0.54
Milk[4], kg/d	26.5 ± 1.5	31.6 ± 1.9	29.8 ± 1.5	0.03	0.46

[1] Cows assigned to CON received a prepartum diet with a DCAD value of +12 mEq/ 100 g of DM, 21-ND received a prepartum diet with a DCAD value of -16 mEq/ 100 g of DM for 21 d prepartum and those assigned to 42-ND received a prepartum diet with a DCAD value of -16 mEq/ 100g for 42 d prepartum.
[2] C1: Control vs. 21-ND and 42-ND, C2: 21-ND vs. 42-ND.
[3] Dry matter intake and energy balance from days -7 through -1 relative to calving.
[4] Dry matter intake, energy balance and milk yield from days 1 through 7 relative to calving.
[5] EB = energy intake – energy requirements.

Table 15. Least squares means of pre- and postpartum body weight, body condition score, postpartum body condition loss and postpartum body weight loss from multiparous cows fed prepartum diets with positive DCAD (CON) for 42 d prepartum or negative DCAD (21-ND or 42-ND) for 21 or 42 d prepartum.

	Treatments[1]			P-value	
Variable	CON	21-ND	42-ND	C1[2]	C2[2]
		Prepartum			
Body weight[3], kg	708.4 ± 22.2	694.2 ± 28.9	712.3 ± 23.3	0.86	0.63
BCS[3,5]	3.3 ± 0.1	3.1 ± 0.1	3.3 ± 0.1	0.29	0.08
		Postpartum			
Body weight[4], kg	629.5 ± 18.5	622.7 ± 23.2	632.1 ± 18.8	0.93	0.76
BCS[4,5]	2.9 ± 0.1	2.8 ± 0.1	3.0 ± 0.1	0.38	0.10
Weight loss[4], kg	43.8 ± 8.4	44.2 ± 11.0	52.0 ± 8.5	0.70	0.58
BCS[5] loss, points	0.2 ± 0.1	0.3 ± 0.1	0.2 ± 0.1	0.55	0.51

[1] Cows assigned to CON received a prepartum diet with a DCAD value of +12 mEq/ 100 g of DM, 21-ND received a prepartum diet with a DCAD value of -16 mEq/ 100 g of DM for 21 d prepartum and those assigned to 42-ND received a prepartum diet with a DCAD value of -16 mEq/ 100g for 42 d prepartum.
[2] C1: Control vs. 21-ND and 42-ND, C2: 21-ND vs. 42-ND.
[3] Measured d -42 through d 0 relative to calving.
[4] Wk 1 weight – wk 4 weight, measured d 0 though d 28 relative to calving.
[5] BCS = body condition score (1-5 scale, 0.25 unit increments).

Table 16. Least squares means of milk yield, 3.5% fat corrected milk (FCM) yield, milk component concentration, component yield, fat: protein, dairy efficiency, SCC and MUN d 0 through d 28 relative to calving from multiparous cows fed prepartum diets with positive DCAD (CON) for 42 d prepartum or negative DCAD (21-ND or 42-ND) for 21 or 42 d prepartum.

	Treatments[1]			P-value	
Variable	CON	21-ND	42-ND	C1[2]	C2[2]
Milk[3], kg/d	39.1 ± 1.7	45.7 ± 2.1	43.8 ± 1.7	0.01	0.50
3.5% FCM[4], kg/d	41.0 ± 2.2	44.1 ± 2.8	43.2 ± 2.3	0.37	0.82
Milk fat, kg/d	1.5 ± 0.1	1.6 ± 0.1	1.6 ± 0.1	0.65	0.84
Milk lactose, kg/d	1.7 ± 0.1	2.0 ± 0.1	1.9 ± 0.1	0.01	0.51
Milk protein, kg/d	1.2 ± 0.1	1.3 ± 0.1	1.3 ± 0.1	0.10	0.97
MUN[5], mg/dL	12.3 ± 0.5	13.3 ± 0.6	14.1 ± 0.5	0.02	0.35
Fat : protein	1.3 ± 0.1	1.2 ± 0.1	1.2 ± 0.1	0.26	0.61
Dairy efficiency[6]	2.5 ± 0.1	2.2 ± 0.2	2.3 ± 0.1	0.25	0.77

[1] Cows assigned to CON received a prepartum diet with a DCAD value of +12 mEq/ 100 g of DM, 21-ND received a prepartum diet with a DCAD value of -16 mEq/ 100 g of DM for 21 d prepartum and those assigned to 42-ND received a prepartum diet with a DCAD value of -16 mEq/ 100g for 42 d prepartum.
[2] C1: Control vs. 21-ND and 42-ND, C2: 21-ND vs. 42-ND.
[3] Milk through 56 d postpartum.
[4] 3.5% FCM = 0.4324 × (kg milk) + 16.2162 × (kg fat), through 28 d postpartum.
[5] Milk urea nitrogen.
[6] 3.5% FCM divided by DMI.
[7] Somatic cell score (1-9 scale, 1 = lowest, 9 = highest).
[8] Somatic cell count (1000's of cells).

Table 17. Least squares means of serum ionized calcium, total plasma calcium and other blood minerals from multiparous cows fed prepartum diets with positive DCAD (CON) for 42 d prepartum or negative DCAD (21-ND or 42-ND) for 21 or 42 d prepartum.

	Treatments[1]			P-value	
Variable	CON	21-ND	42-ND	C1[2]	C2[2]
		Prepartum			
Ca, Ionized, mg/dL	4.78 ± 0.1	4.74 ± 0.1	4.81 ± 0.1	0.95	0.49
Ca, Total, mg/dL	7.53 ± 0.4	7.79 ± 0.5	8.17 ± 0.4	0.41	0.58
K, mg/dL	71.58 ± 5.4	82.48 ± 7.0	72.25 ± 5.4	0.41	0.26
Mg, mg/dL	0.98 ± 0.1	1.04 ± 0.2	1.22 ± 0.1	0.26	0.31
		Postpartum			
Ca, Ionized, mg/dL	4.60 ± 0.1	4.68 ± 0.1	4.69 ± 0.1	0.28	0.91
Ca, Total, mg/dL	6.52 ± 0.3	6.80 ± 0.3	7.53 ± 0.3	0.07	0.10
Ca, Nadir, mg/dL	5.62[a] ± 0.3	5.68[a] ± 0.4	6.65[b] ± 0.3	0.16	0.05
K, mg/dL	65.97 ± 4.2	76.35 ± 5.1	75.66 ± 4.2	0.07	0.92
Mg, mg/dL	1.06 ± 0.1	1.02 ± 0.1	1.27 ± 0.1	0.48	0.07

[1] Cows assigned to CON received a prepartum diet with a DCAD value of +12 mEq/ 100 g of DM, 21-ND received a prepartum diet with a DCAD value of -16 mEq/ 100 g of DM for 21 d prepartum and those assigned to 42-ND received a prepartum diet with a DCAD value of -16 mEq/ 100g for 42 d prepartum.
[2] C1: Control vs. 21-ND and 42-ND, C2: 21-ND vs. 42-ND.

Table 18. Least squares means of energy related metabolites and liver lipid and carbohydrates from multiparous cows fed prepartum diets with positive DCAD (CON) for 42 d prepartum or negative DCAD (21-ND or 42-ND) for 21 or 42 d prepartum.

Variable	Treatments[1] CON	21-ND	42-ND	P-value C1[2]	C2[2]
		Prepartum			
Glycogen[3], %	5.4 ± 0.5	5.4 ± 0.7	5.9 ± 0.5	0.69	0.63
NEFA[4], µEq/L	233.4 ± 27.5	220.6 ± 34.4	231.2 ± 28.2	0.83	0.82
Total lipid[3], %	4.3 ± 0.2	4.9 ± 0.3	4.6 ± 0.2	0.19	0.40
Triglyceride[5], %	0.6 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	0.31	0.59
Total lipid: triglyceride	0.1 ± <0.1	0.1 ± <0.1	0.1 ± <0.1	0.17	0.60
		Postpartum			
BHBA[6], mg/dL	13.9 ± 2.0	9.1 ± 2.5	10.7 ± 2.0	0.12	0.72
Glycogen[7], %	2.2 ± 0.3	2.5 ± 0.3	2.6 ± 0.3	0.38	0.63
NEFA[8], µEq/L	584.2 ± 61.5	469.0 ± 76.4	606.3 ± 62.0	0.56	0.17
Total lipid[7], %	9.8 ± 1.2	6.8 ± 1.5	8.3 ± 1.3	0.12	0.48
Triglyceride[9], %	5.5 ± 0.8	3.2 ± 1.0	4.4 ± 0.9	0.12	0.34
Total lipid: triglyceride	2.8 ± 0.6	2.1 ± 0.7	2.6 ± 0.6	0.48	0.62

[1] Cows assigned to CON received a prepartum diet with a DCAD value of +12 mEq/ 100 g of DM, 21-ND received a prepartum diet with a DCAD value of -16 mEq/ 100 g of DM for 21 d prepartum and those assigned to 42-ND received a prepartum diet with a DCAD value of -16 mEq/ 100g for 42 d prepartum.
[2] C1: Control vs. 21-ND and 42-ND, C2: 21-ND vs. 42-ND.
[3] Percent of wet weight from liver samples from day -14 relative to calving.
[4] Non-esterified fatty acid analysis of serum from days -28, -21, -14, -7, -3 and -1 relative to calving.
[5] Percent of TL from day -14 relative to calving.
[6] Beta-hydroxybutyrate analysis of serum from days 1, 7, 14 and 21 relative to calving.
[7] Percent of TL from day 7 and 14 relative to calving.
[8] Non-esterified fatty acid analysis of serum from days 1, 7, 14 and 21 relative to calving.
[9] Percent of wet weight from liver samples from days 7 and 14 relative to calving.

Colostrum Yield by Multiparous Cows is Positively Correlated with Prepartum Body Fat Mobilization

One hundred and twenty Holstein and Holstein-cross multiparous dairy cows from two studies in 2010 and 2011 were used in a correlation analysis to determine if prepartum nutrition, metabolism, and management factors affect colostrum yield (CY). Cows were fed moderate-energy high-forage diets containing corn silage, wheat straw, alfalfa hay, ground corn, and molasses and protein supplements. Prepartum diets averaged 14.5% CP, 40.5% NDF, 1.5 Mcal NE_L/kg DM, 16.8 % starch, 6.0% sugar, 2.0% fat. Cows averaged 42.7 ± 8.1 d dry, 13.6 ± 0.9 kg DMI/d, 3.1 ± 1.1 lactations and postpartum 305ME = 10,516 ± 2,203 kg. All cows were from the St Paul Dairy Research Unit and were managed similarly. CY was not significantly affected by treatment or by study. Samples were collected and analyzed using the same techniques for both studies. Data were pooled and subjected to Pearson Correlation analysis in SAS. Correlation coefficients and p-values (Table 19) were calculated among CY, parity, days dry, calf birth weight, average prepartum DMI, crude protein intake (CPI), neutral detergent fiber intake (NDFI), sugar intake (SI), starch intake (STI), mature equivalent 305 milk yield (305 ME), pre- and postpartum serum NEFA concentration, and pre- and postpartum liver triglyceride concentration. CY averaged 7.9 ± 4.2 kg with a minimum yield of 0.91 kg and maximum yield of 21.6 kg. Twenty six percent of cows produced < 5.0 kg colostrum. CY tended to be correlated (r = 0.19; P = 0.06) with calf birth weight. CY was positively correlated with serum NEFA 7 d prepartum (r = 0.40; *P* < 0.05), serum NEFA 1 d postpartum (r = 0.53; P < 0.05), serum NEFA 7 d postpartum (r = 0.29; *P* < 0.05), serum NEFA 14 d postpartum (r = 0.19; *P* < 0.05). CY was positively correlated with liver triglyceride concentration 7 d postpartum (r = 0.28; *P* < 0.05) and 14 d postpartum (r = 0.24; *P* < 0.05). Prepartum nutrient intake; DMI, CPI, NDFI, SI, and STI were not significantly correlated with CY. CY was not significantly correlated with 305ME (r = 0.07; *P* = 0.6) Feeding strategies that reduce prepartum serum NEFA also appear to reduce colostrum yield.

Table 19. Correlation coefficients (r) and P-values among prepartum nutrition and management factors, liver triglyceride, serum NEFA and colostrum yield.

	Correlation (r)	P-value
Parity	-0.11	0.24
Twin	0.08	0.40
Days dry	0.14	0.15
Calf birth weight	0.19	0.06
305ME	0.07	0.55
Liver triglyceride - 14	0.113	0.28
Liver triglyceride + 7	0.28	<0.05
Liver triglyceride + 14	0.24	0.05
Liver triglyceride + 28	0.23	0.12
Serum NEFA -28	0.08	0.44
Serum NEFA -14	0.15	0.14
Serum NEFA -7	0.40	<0.05
Serum NEFA +1	0.53	<0.05
Serum NEFA +7	0.29	<0.05
Serum NEFA +14	0.19	0.05
Serum NEFA +28	0.08	0.58
	Prepartum nutrient intake	
DMI	0.07	0.46
OM intake	0.07	0.46
CP intake	-0.1	0.30
ADF intake	-0.03	0.73
NDF intake	-0.04	0.96
Sugar intake	0.08	0.43
Starch intake	-0.10	0.30

Conclusions

Isocaloric diets with orchard grass resulted in higher postpartum DMI during the first month of lactation and greater milk yield on week one compared with wheat straw. Milk yield tended to be higher for wheat straw vs. low quality grass hay and wheat straw also had lower postpartum NEFA, higher liver glycogen and tended to have lower liver triglyceride:glycogen. Sugar supplementation decreased postpartum DMI and energy balance compared with starch supplementation but did not affect yield of milk or 3.5% fat corrected milk yield resulting in an increase in dairy efficiency. Feeding negative DCAD (-15 mEq/100 g) for 21 or 42 d prepartum utilizing acidified fermentation products positively affected mineral homeostasis, postpartum DMI, and milk production in multiparous cows. Multiparous cows fed moderate energy high forage diets averaged 8.0 kg of colostrum. Colostrum yield was positively correlated with calf body weight but no significant correlations were found among colostrum yield and prepartum dietary starch, sugar, protein or DCAD. Pre and postpartum serum NEFA and liver triglycerides were positively correlated with colostrum yield.

References

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

Broderick, G.A., N.D. Luchini, S.M. Reynal, G.A. Varga, and V.A. Ishler. 2008. Effect on production of replacing dietary starch with sucrose in lactating dairy cows. J. Dairy Sci. 91:4801-4810.

Broderick, G.A., and W. J. Radloff. 2004. Effect of molasses supplementation on the production of lactating dairy cows fed diets based on alfalfa and corn silage. J. Dairy Sci. 87:2997-3009.

Colucci, P.E., L.E. Chase, and P.J. Van Soest. 1982. Feed intake, apparent diet digestibility, and rate of particulate passage in dairy cattle. J. Dairy Sci. 65:1445-1456.

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.

Dias, R.S., H.O. Patino, S. López, E. Prates, K.C. Swanson, and J. France. 2011. Relationships between chewing behavior digestibility, and digesta passage kinetics in steers fed oat hay at restricted and ad libitum intakes. J. Anim. Sci. 89:1873-1880.

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.

Firkins, J L., B.S. Oldick, J. Pantoja, C. Reveneau, L.E. Gilligan, and L. Carver. 2008. Efficacy of liquid feeds varying in concentration and composition of fat, nonprotein nitrogen, and nonfiber carbohydrates for lactating cows. J. Dairy Sci. 91:1969-1984.

Galvani, D.B., C.C. Pires, T.P. Wommer, F. Oliveira, and M.F. Santos. 2010. Chewing patterns and digestion in sheep submitted to feed restriction. J. Anim. Physiol. Anim. Nutr. 94:366-373.

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.

Hammon, H., G. Stürmer, F. Schneider, A. Tuschscherer, H. Blum, T. Engelhard, A. Genzel, R. Staufenbiel, and W. Kanitz. 2009. Performance and metabolic and endocrine changes with emphasis on glucose metabolism on high-yielding dairy cows with high and low fat content in liver after calving. J. Dairy Sci. 92:1554-1566.

Hoffman, P.C., C.R. Simson, and M. Wattiaux. 2007. Limit feeing of gravid Holstein heifers: Effects on growth, manure nutrient excretion and subsequent early lactation performance. J Dairy Sci. 92:90:946-954.

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.

Holtenius, K., S. Agenäs, D. Delavaud, and Y. Chilliard. 2003. Effect of feeding intensity during the dry period. 2. Metabolic and hormone response. J. Dairy Sci. 86:883-891.

Horst, R.L. and J.P. Goff. 1997. Milk fever and dietary potassium. Pages 181-189 in Proc. Cornell Nutr. Conf. Feed Manuf., Rochester, NY. Cornell Univ., Ithaca, NY.

Hosseinkhani, A., T.J. DeVries, K.L. Proudfoot, R. Valizadeh, D.M. Veira, and M.A.G. von Keyserlingk. 2008. The Effects of feed bunk competition on the feed sorting behavior of close-up dry cows. J. Dairy Sci. 91:1115-11121.

Janovick, N.A., Y.R. Boisclair, and J.K. Drackley. 2011. Prepartum dietary energy intake affects metabolism and health during the periparturient period in primiparous and multiparous Holstein cows. J. Dairy Sci. 94:1385-1400.

Janovick, N.A. and J.K. Drackley. 2010. Prepartum dietary management of energy intake affects postpartum intake and lactation performance by primiparous and multiparous Holstein cows. J. Dairy Sci. 93:3086-3102.

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., M. L. Raeth-Knight, and J.G. Linn. 2010. Diets containing thirty percent wheat straw or orchard grass hay fed at either ad libitum or restricted intake prepartum have modest effects on postpartum performance. J. Anim. Sci. Vol. 88, E-Suppl. 2/ J. Dairy Sci. Vol. 93, E-Suppl. 1/Poult. Sci. Vol. 89, E-Suppl. 1. Page 838. Abstract# 1041.

Miller, W.F., J.E. Shirley, J.M. Rottinghaus, E.C. Titgemeyer, and D.E. Johnson. 2005. Effect of dietary inclusion of cane molasses in dry cow diets on prepartum and postpartum performance. J. Dairy Sci. 88:Suppl. 1:221 (Abstr. #322).

Miller, W.F., B.J. Johnson, E.C. Titgemeyer, J.F. Smith, J.E. Shirley, and T.G. Nagaraja. 2007. Effect of cane molasses on ruminal absorptive capacity of dairy cows during the periparturient period. Proc. Midwest Sect. Amer. Dairy Sci. Assoc.: Page 88. (Abstr. #276).

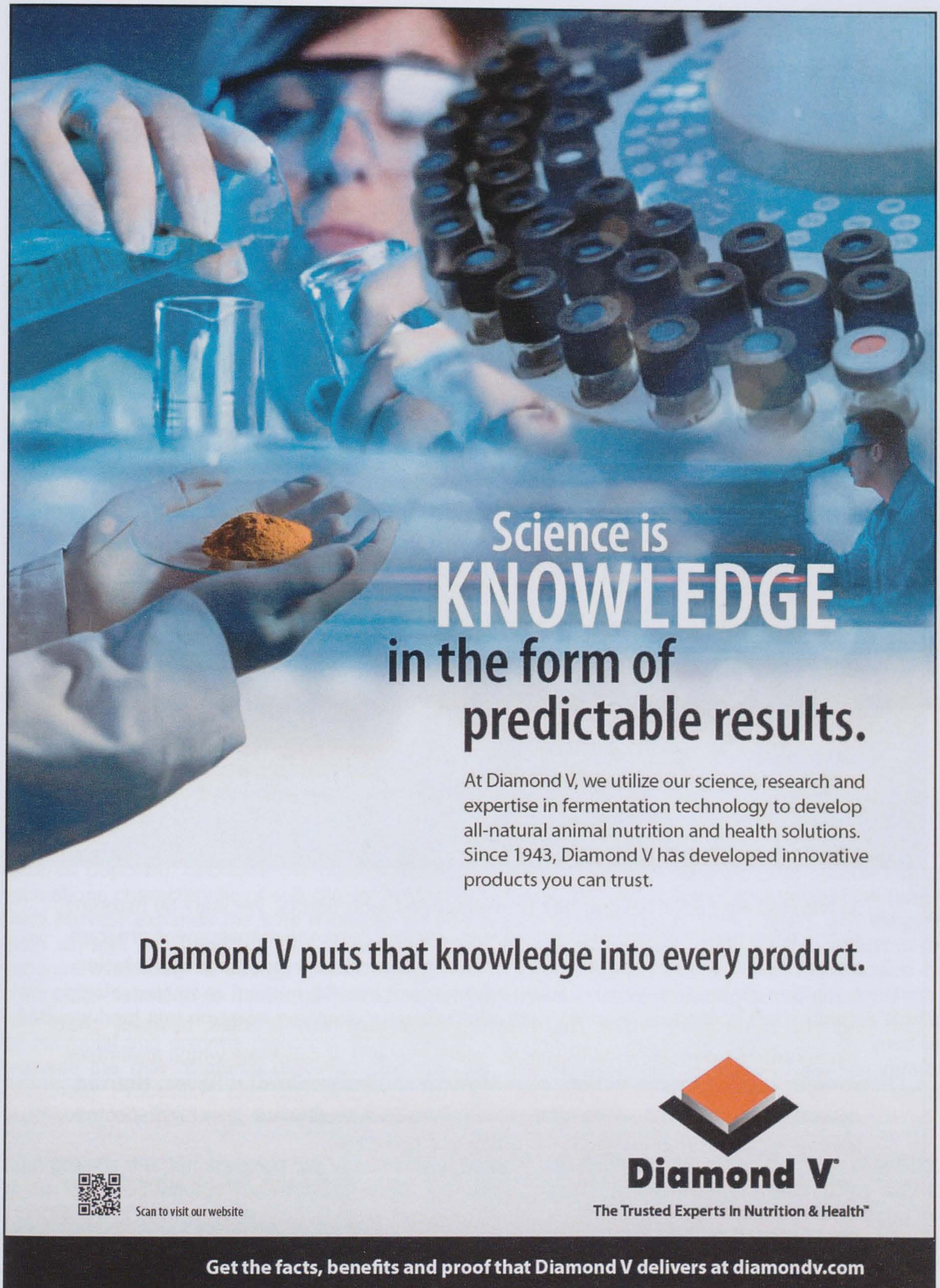
Nombekela, S.W. and M.R. Murphy. 1995. Sucrose supplementation and feed intake of dairy cows in early lactation. J. Dairy Sci. 78:880-885.

Penner, G.B. and M. Oba. 2009. Increasing dietary sugar concentration may improve dry matter intake, ruminal fermentation, and productivity of dairy cows in the postpartum phase of the transition period. J. Dairy Sci. 92:3341-3353.

Wathes, D.C., Z. Cheng, W. Chowdhury, M.A. Fenwick, R. Fitzpatrick, D.G. Morris, J. Patton, J.J. Murphy. 2009. Negative energy balance alters global gene expression and immune responses in the uterus of postpartum dairy cows. Physiol. Genomics 39:1-13.

Winkelman, L.A., T.H. Elsasser, and C.K. Reynolds. 2008. Limit feeding a high energy diet to meet energy requirements in the dry period alters plasma metabolite concentration but does not affect intake or milk production in early lactation. J. Dairy Sci. 91:1067-1079.

Zanton, G.I. and A.J. Heinrichs. 2007. The effects of controlled feeding of a high-forage or high-concentrate ration on heifer growth and first-lactation milk production. J. Dairy Sci. 90:3388-3396.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