FEEDING THE FRESH COW: FIBER CONSIDERATIONS

S. E. LaCount, M. E. Van Amburgh, and T. R. Overton
Department of Animal Science
Cornell University

INTRODUCTION

The transition from pregnancy to lactation is a time of great metabolic adaptation for the dairy cow that can often end in less than ideal circumstances. With the onset of lactation, the demands for glucose, amino acids, and fatty acids almost double (Bell, 1995) and coupled with the dynamics of DMI, cows are typically in negative nutrient balance just after parturition. In this negative nutrient state body reserves are mobilized as circulating NEFA and BHBA, and utilized as fuels in many tissues to meet energy needs. Elevated levels of NEFA and BHBA in the periparturient period increase risk for diseases such as displaced abomasum, ketosis, and metritis (Ospina et al., 2010). Research has shown that feeding higher energy rations in the immediate postpartum period can reduce negative energy balance and reduce circulating NEFA and BHBA (Rabelo et al., 2003, McCarthy et al., 2015a, McCarthy et al., 2015b). Generally higher energy fresh cow rations contain high amounts of NFC; however, large changes in diet composition, especially in the transition period, can lead to subacute ruminal acidosis (Nocek, 1997, Penner et al., 2007, Williams et al., 2015) and detrimental effects on metabolism and production (Stone, 2004).

The potential to further refine carbohydrate nutrition of fresh cow rations through the use of different pools of fiber has remained largely unexplored. Physically effective fiber has previously been investigated in regards to mitigating SARA through increased rumination and chewing activity (Stone, 2004), though evidence in the immediate postpartum period is lacking. In mid-lactation rations $uNDF_{240}$ has recently been investigated as a possible regulator of both dry matter intake and rumen health (Cotanch et. al., 2014). In a ration with low $uNDF_{240}$ rumen health could be compromised, though with high $uNDF_{240}$, intake can be limited due to gut fill. Previous case study data from the Overton lab would indicate that cows fed higher $uNDF_{240}$ (10.7% of ration DM, intake 0.36% of BW) had higher DMI and improved health status when compared to cows fed low $uNDF_{240}$ (8.3% of ration DM, intake 0.27% of BW) in the postpartum period (McCarthy et. al, 2014c). To the authors' knowledge, there are few published data investigating the effects of modulating $uNDF_{240}$ and overall digestion pools in the periparturient period. Gaining insight into the ideal lower and upper bounds of $uNDF_{240}$ and digestibility pools in the fresh period could prove valuable for increasing animal health and productivity as sufficient $uNDF_{240}$ might help increase DMI during the immediate postpartum period, but excessive $uNDF_{240}$ and slowly digestible NDF might limit DMI during the same period.

Another opportunity to increase DMI and overall energy intake during the immediate postpartum period could be to focus on the digestible fiber fraction through use of corn silage hybrids with high NDF digestibility such as brown mid-rib (BMR) corn silage. Feeding BMR corn silage in the prepartum and postpartum period has been found to increase intake and milk production in the early lactation period (Stone et al., 2012), while feeding BMR only the postpartum period decreased BW loss and increased post-peak lactation milk yield (Holt et al., 2013). The positive milk production effects shown by Stone et al. (2012) were shown to carry over through post-peak lactation even after cows were switched to a conventional corn silage, indicating lasting effects due to changes in intake and energy balance early in lactation. Utilizing all of the different aspects of fiber within postpartum rations could provide a more energy dense ration while also being mindful to rumen health.

EXPERIMENT 1: THE EFFECTS OF VARYING $uNDF_{240}$ AND peNDF CONTENT OF FRESH RATIONS ON PERFORMANCE AND METABOLISM

Fifty-six multiparous Holstein cows were fed a common prepartum ration beginning 28 d prior to expected parturition. Cows were assigned randomly to one of two postpartum diets differing in content of $uNDF_{240}$ and peNDF with randomization restricted to control for parity and previous lactation 305 d mature equivalent milk production. Treatment diets, high fiber (**HF**, n=27) and low fiber (**LF**, n=29), were formulated for equivalent metabolizable protein (MP) and starch, with higher fiber levels achieved through the addition of chopped straw in the HF diet. At 29 days in milk (DIM), HF cows were switched to the LF diet and all cows were fed the LF diet through 42 DIM.

Cows were housed in tie-stalls and fed once daily at approximately 0800 h throughout the study. Individual intakes were calculated by weighing the feed delivered and refused daily. A refusal rate of 10% was targeted daily to allow for ad-libitum intake. All rations were formulated using CNCPS v6.55 and ingredient and analyzed composition of diets are presented in Table 1. Weekly samples of TMR and all feed ingredients were collected for determination of DM which was used to adjust feed inclusion rates and to calculate DMI. At the end of the experiment all retained feed samples were ground and composited by 4-wk intervals over the duration of the study. Composite samples were sent to a commercial laboratory (Cumberland Valley Analytical Services, Hagerstown, MD) for wet chemistry and in-vitro fermentation analysis.

Body weights and BCS were measured weekly throughout the experiment. BCS was assigned by two scorers weekly and averaged for analysis. After calving, all cows were milked 3x daily and individual milk weights were recorded. Once weekly milk samples were collected from three consecutive milkings and sent to a commercial laboratory (DairyOne, Ithaca, NY) for analysis of milk composition and SCC. Milk fat and milk protein were used to calculate FCM and ECM. Weekly energy balance was calculated according to NRC (2001). Rumination time was recorded in 2-h intervals over the duration of the study using rumination collars (HR tags; SCR Dairy, Madison, WI).

Blood samples were collected via coccygeal venipuncture 2x per week prior to parturition, daily from the day of parturition through 7 DIM, 3x per week through 21 DIM and 2x per week through 42 DIM. Plasma was harvested, snap frozen in liquid nitrogen and stored at -20ºC until analysis. Samples were analyzed for BHBA, NEFA, and glucose. Liver biopsies were obtained from a subset of 40 cows on d 7 ± 1.1 (mean ± SD) and 14

± 1.0 postpartum and incubated in an *in vitro* system to determine liver capacity to convert [1-^{14}C]propionate to glucose and CO_2 and [1-^{14}C]palmitic acid to CO_2, esterified products, and acid soluble products.

Statistical analyses were conducted using the statistical software SAS (version 9.4, SAS Institute Inc., Cary, NC). Repeated measures data were analyzed using the REPEATED statement in the MIXED procedure of SAS (Littell et al., 1996) with model effects of treatment, time, and treatment × time. Covariate measurements collected in the week of enrollment were included in all models.

Table 1. Ingredients and nutrient profile of rations (mean ± SD), obtained through wet chemistry analysis and in vitro fermentation.

	Diet		
Item	**Prepartum**	**Low Fiber (LF)**	**High Fiber (HF)**
Ingredients, % of ration DM			
Conventional corn silage	45.21	42.31	38.46
Alfalfa hay	-	10.58	10.58
Straw	20.84	1.15	8.65
Corn meal	2.43	17.64	20.15
Soybean meal	-	6.03	4.73
Wheat middlings	-	4.82	1.58
Amino Plus	5.9	4.34	5.31
Canola meal	3.47	1.61	3.88
Corn gluten feed	1.74	1.61	0.47
Blood meal	2.43	0.95	1.09
Soybean hulls	6.95	2.41	-
Citrus pulp	4.52	-	0.79
Energy Booster	-	1.29	1.58
Rumensin, mg/d[1]	439	365	334
Other	6.4	2.3	2.3
Analyses, % of ration DM			
aNDFom	43.1 ± 0.3	32.8 ± 1.4	35.3 ± 2.3
ADF	29.0 ± 0.5	21.3 ± 1.1	22.9 ± 2.1
Starch	15.6 ± 0.3	24.8 ± 1.7	24.6 ± 2.3
Sugar	3.5 ± 0.4	5.0 ± 0.7	3.9 ± 0.1
Fat	2.3 ± 0.2	3.3 ± 0.2	3.2 ± 0.2
$uNDF_{240}$	12.8 ± 0.5	9.5 ± 0.4	12.2 ± 1.6
peNDF	33.3	21.6	23.2
MP, g/kg DM[1]	89.0	112.1	108.0

[1] Formulated value given by Cornell Net Carbohydrate and Protein System v. 6.55 using actual mean intakes

Intake and production results are presented in Table 2. Postpartum intake was lower for cows fed HF in wk 3 and 4 (P<0.01) compared to cows fed LF. After the diet change, in wk 5 and 6 cows fed HF obtained similar intake as cows fed LF throughout the experiment. Despite differences in intake, no differences were detected for rumination. Milk yield was lower for cows fed HF in week 4 (P<0.01) than cows fed LF, no treatment differences were seen in milk components or ECM.

Table 2. The effect of low fiber and high fiber diets in the early postpartum period on intake, milk yield, and rumination for 1 to 6 wk postpartum.

				***P*-Value**	
Item	**LF**	**HF**	**SEM**	**Trt**	**Trt×Time**
Prepartum DMI, kg/d	15.5			-	-
Postpartum DMI, kg/d	23.6	22.2	0.3	0.002	<0.001
uNDF intake, %BW[1]	0.29	0.34	0.01	<0.001	0.047
Milk yield, kg/d	46.2	44.7	1.0	0.26	0.001
Fat, %	3.72	3.87	0.85	0.20	0.14
FCM, kg/d	47.9	47.6	1.1	0.83	0.07
Protein, %	3.09	3.02	0.05	0.30	0.56
Lactose, %	4.78	4.76	0.05	0.66	0.68
Total solids, %	12.57	12.64	0.13	0.70	0.33
ECM, kg/d	48.2	47.3	1.1	0.55	0.12
Rumination, min/d	544	543	8	0.90	0.14

[1]Calculated only for weeks where treatment diets differ (1 to 4 wk)

Blood metabolites and calculated energy balance are shown in Figure 2 (A-D). As expected given intake differences, cows fed HF had had higher NEFA and BHBA, and lower blood glucose and energy balance at different points through the experiment (Trt x Time P=0.01). Again, after cows assigned to the HF treatment were fed the LF diet at 29 DIM, cows from both treatment groups had similar blood metabolite concentrations and calculated energy balance by wk 5 and 6.

In-vitro liver incubation results are shown in Figure 3 and Table 3 below. Cows fed HF tended to have higher rates of esterification and lower rates of oxidation of [1-^{14}C]palmitic acid, which is consistent with the differences in intake, blood metabolites and overall energy balance discussed above. There were no treatment differences in [1-^{14}C]propionate metabolism, however there was an overall effect of day of biopsy for many products which is shown in Table 3. Overall, the conversion of [1-^{14}C]palmitic acid to esterified products decreases, CO_2 oxidation increases, and the ratio of Glucose:CO_2 for [1-^{14}C]propionate metabolism increases as the cows get later in lactation. This evidence demonstrates the changes in liver metabolism that are occurring as cows are progressing more towards a positive energy balance state.

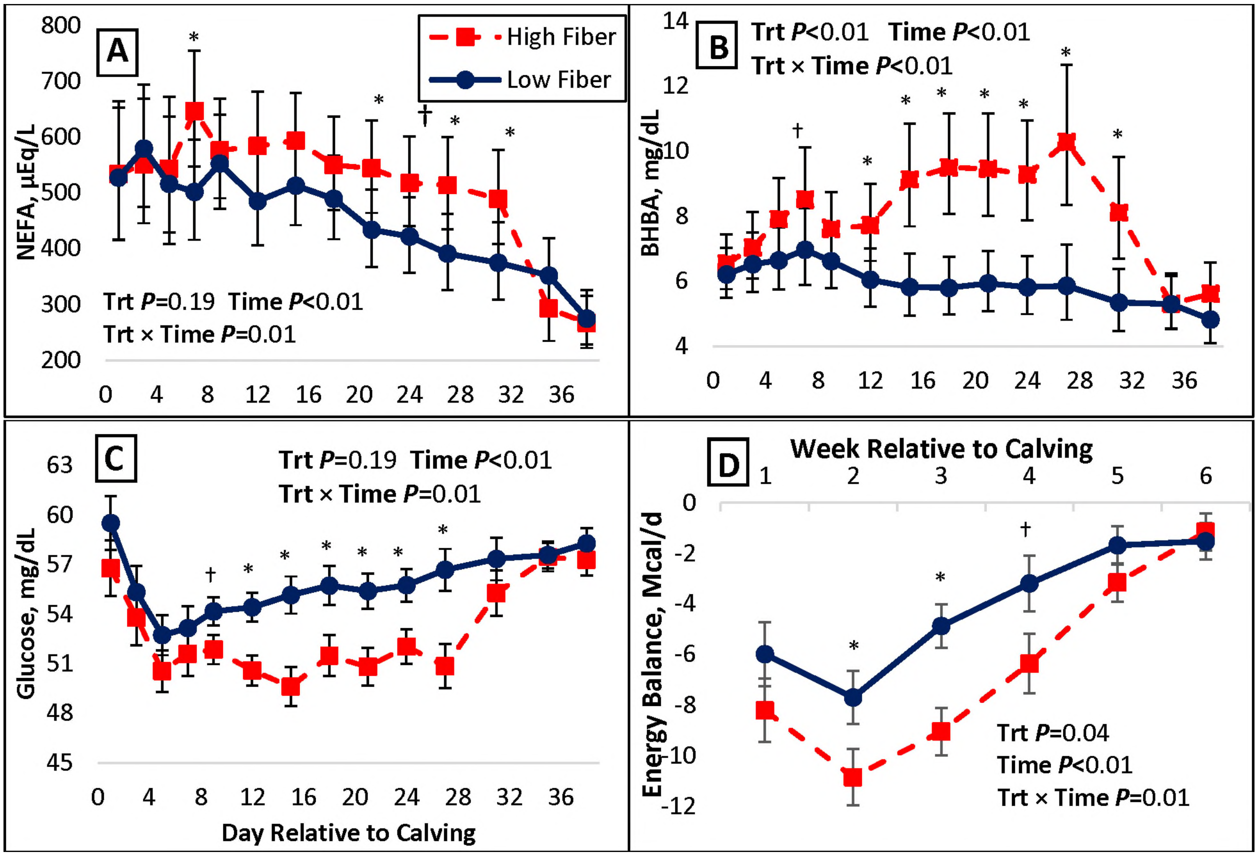

Figure 1. Plasma NEFA (A), BHBA (B), glucose (C), and energy balance (D) by time relative to calving, NEFA and BHBA reported as geometric means with back transformed 95% confidence intervals. Significant differences indicted with an asterisk (*), trends with a cross (†). Energy balance was calculated according to NRC (2001).

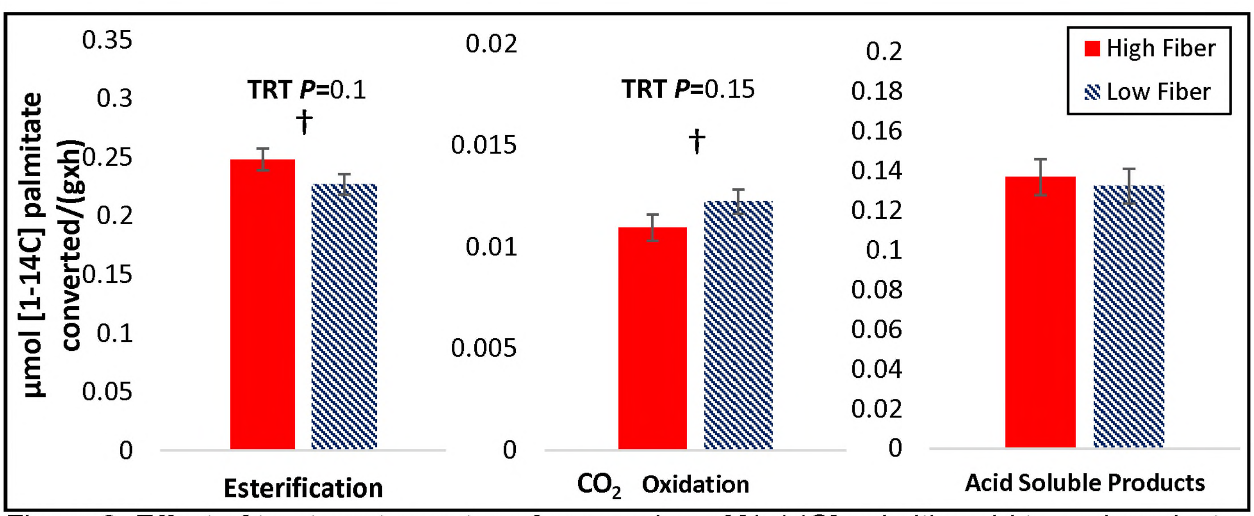

Figure 3. Effect of treatment on rates of conversion of [1-14C] palmitic acid to end products; esterified products, CO_2, and acid soluble products by bovine liver slices after in vitro incubation. Trends for differences (P<0.15) indicated with a cross (†).

Table 3. Effect of DIM on mean rates of [1-^{14}C]palmitate and [1-^{14}C]propionate metabolism by day of biopsy.

				***P*-Value**	
Item	**Day 7**	**Day 14**	**SEM**	**Time**	**Trt×Time**
Palmitate	-µmol/(g x h)-				
Esterified Products	0.244	0.232	<0.01	0.007	0.364
CO_2 Oxidation	0.010	0.013	0.01	0.076	0.343
Acid Soluble Products	0.133	0.136	0.01	0.681	0.890
Propionate					
Glucose:CO_2	0.530	0.564	0.02	0.148	0.937

In this trial, the formulated diets focused on $uNDF_{240}$ demonstrated that the levels achieved in the low fiber diet (9.5% of DM, 0.29% of BW) were adequate whereas the levels in the high fiber diet (12.2% of DM, 0.34% of BW) were gut fill limiting. It is important to note that, as a result of variation in forage composition, actual $uNDF_{240}$ levels were more than one percentage unit higher than intended, and the LF diet in the current study was intermediate to the levels characterized in the McCarthy et al. (2014) study. Though not a definitive limit, these data would suggest a maximum for $uNDF_{240}$ intake of ~0.34% of BW in the postpartum period, with an optimum range of $uNDF_{240}$ intake ranging from 0.29 to 0.35% of BW or as a percentage of the diet 9.5% to 11% DM. However, it is important that all fiber pools be appropriately characterized to ensure all of the NDF pools are accounted for to fully understand what was first limiting for rumen fill. Overall, cows fed increased levels of $uNDF_{240}$ and peNDF resulted in cows that were restricted in intake thus in a more severe negative energy balance. This negative energy balance was reflected not only by blood metabolites, but through impaired liver metabolism as well. However, the detrimental effects of this restriction did not appear to carryover once cows switched to a lower fiber diet. It appears that $uNDF_{240}$ and overall forage digestibility and pool size likely plays an important role in regulating intake in the early fresh period, this area warrants further investigation.

EXPERIMENT 2: STRATEGIES FOR OPTIMIZING DIETARY ENERGY AVAILABILITY IN FRESH RATIONS

Eighty-five multiparous Holstein cows were enrolled at 28 d prior to expected parturition and assigned to treatments at 21 d before calving in a completely randomized design with a 2 X 2 factorial arrangement of treatments. Cows were randomly assigned to treatment with randomization restricted for parity and previous 305-d mature equivalent milk yield. Treatment variables were corn silage type [conventional corn silage, TMF hybrid (**CON**) vs. brown mid-rib, BM3 hybrid (**BMR**), Mycogen Seeds, Indianapolis, IN] and Rumensin supplementation [0 mg/d prepartum and postpartum (**NO**) vs. 330 mg/d prepartum and 450 mg/d postpartum (**RUM**), Elanco Animal Health, Indianapolis, IN]. For inclusion in the final dataset, cows had to be fed the prepartum treatments for a minimum of 9 d. At parturition, cows were fed a fresh diet formulated to follow their assigned treatment scheme (CON vs. BMR and NO vs. RUM) through 42 DIM. Treatment diets were formulated to be the same except for the type of corn silage or Rumensin mix, ration ingredients and analyzed composition are presented in Table 4. In the dataset 22 cows were in the conventional corn silage with Rumensin supplementation group (**CON-RUM**), and 21 cows were in each of the conventional corn silage, no Rumensin supplementation (**CON-NO**), BMR corn silage, no Rumensin supplementation (**BMR-NO**), BMR corn silage with Rumensin supplementation (**BMR-RUM**) treatment groups.

In terms of housing, feeding, feed samples, BW, BCS, and milking cows were managed similarly to the previously described experiment with few differences. For feeding, basal TMR was delivered for each period and forage type, containing forages and a base grain. Small inclusion pelleted grain mixes (to deliver RUM or NO) were then added to small batches of the base TMR to be mixed before delivery to the animals. Milk samples were collected 2x weekly for the first two weeks of lactation and weekly thereafter. Milk composition was analyzed in the Barbano Lab at Cornell University using mid-NIR techniques (Barbano et al., 2014), though these data have yet to be analyzed. Blood samples were collected via coccygeal venipuncture 1x per week prior to parturition, 2x per week for the first 2 weeks postpartum, and 1x per week through 42 DIM. Prior to centrifugation and harvesting plasma, whole blood was used to determine BHBA using the NovaVet (Nova Biomedical, Billerica, MA) handheld ketone meter. Plasma was then harvested and stored until study completion for analysis of NEFA.

Prepartum and postpartum data were analyzed and will be presented separately. Statistical analyses were performed using the statistical software SAS (version 9.4, SAS Institute Inc., Cary, NC). Repeated measures data were analyzed using the REPEATED statement in the MIXED procedure of SAS (Littell et al., 1996). Fixed effects were corn type, Rumensin treatment, time, all 2-way interactions, and a 3-way interaction of corn, rumensin, and time. Covariate measurements collected in the week prior to receiving treatment diet were included in all models.

Table 4. Formulated ingredient composition of diets for which ingredients besides corn silage type differed.

	Prepartum		**Postpartum**	
Item	**NO**	**RUM**	**NO**	**RUM**
Ingredients, % of ration DM				
Corn silage	51.67	51.67	51.46	51.46
Hay Crop Silage	-	-	10.65	10.65
Straw	23.33	23.33	2.66	2.66
Corn meal	-	-	15.08	15.08
Canola meal	4.57	4.57	6.45	6.45
Amino Plus	4.0	4.0	5.32	5.32
Blood meal	1.67	1.67	1.77	1.77
Wheat middlings	1.93	1.92	1.40	1.39
Soybean meal	0.67	0.67	0.48	0.48
Citrus pulp	3.67	3.67	-	-
Rumensin, mg/d[1]	0	336.9	0	449.7
Other	8.96	8.96	5.19	5.19

Table 4. The nutrient profile (analyzed by NIR of weekly samples of fresh TMR) of the diets (mean ± SD).

Item	Prepartum CON	Prepartum BMR	Postpartum CON	Postpartum BMR
Analyses, % of ration DM				
aNDFom	44.0 ± 3.2	41.6 ± 1.5	33.2 ± 2.0	32.4 ± 1.7
ADF	29.5 ± 1.8	27.2 ± 1.2	21.9 ± 1.7	20.7 ± 1.4
Starch	20.3 ± 2.1	21.1 ± 1.0	27.0 ± 1.1	26.7 ± 1.8
Sugar	4.7 ± 0.6	5.4 ± 0.4	4.0 ± 0.9	4.2 ± 1.0
Fat	2.7 ± 0.2	2.8 ± 0.2	4.3 ± 0.4	4.4 ± 0.3
$uNDF_{240}$	17.1 ± 1.9	14.6 ± 1.2	11.2 ± 1.1	10.1 ± 1.1
peNDF[1]	35.1	35.3	22.8	23.4
MP, g/kg DM[1]	94.5	96.5	115.5	117.2

[1] Formulated value given by Cornell Net Carbohydrate and Protein System v. 6.5 using actual mean intakes

Intake and performance results are presented in Table 5 and Figure 4. In the prepartum period, DMI was higher for cows fed BMR than those fed CON (*P*=0.03) corn silage, while cows fed RUM had lower intake than cows without RUM supplementation (*P*<0.01). There were no significant interactions between source of corn silage and Rumensin. Postpartum there were no significant differences in intake due to corn silage, Rum, or any interaction. Milk yield however, was higher for cows fed BMR compared to cows fed CON corn silage (*P*=0.05). There was also a three way interaction of corn silage, Rum, and Time where BMR-RUM had higher milk yield compared to CON-NO cows in weeks 5 and 6 postpartum (*P*=0.02), these data are in Figure 4.

Table 5. Main effect means for prepartum and postpartum intake and milk yield.

Item	Corn Silage CON	Corn Silage BMR	SEM	Rumensin NO	Rumensin RUM	SEM	*P*-Value Corn	*P*-Value Rum	*P*-Value C×R×T[1]
Prepartum									
Intake, kg/d	14.0	14.7	0.21	14.5	13.9	0.21	0.03	<0.01	0.85
Postpartum									
Intake, kg/d	23.0	23.3	0.39	23.3	23.0	0.39	0.57	0.55	0.44
Yield, kg/d	45.8	48.3	0.86	46.7	47.4	0.86	0.05	0.61	0.02

[1]Interaction of Corn silage × Rumensin × Time, no other interactions for these variables were significant.

Prepartum and postpartum blood metabolite results are in Table 6. In the prepartum period cows fed BMR had lower NEFA than cows fed CON (*P*=0.02), and cows fed RUM had lower BHBA than cows without Rumensin (*P*=0.04). In the postpartum period cows fed BMR had lower NEFA and BHBA (*P*<0.01) than cows fed CON corn silage. Cows fed RUM tended to have lower NEFA (*P*=0.06), and had lower BHBA than cows without Rumensin. There were no interactions of corn silage type and Rumensin supplementation in either period.

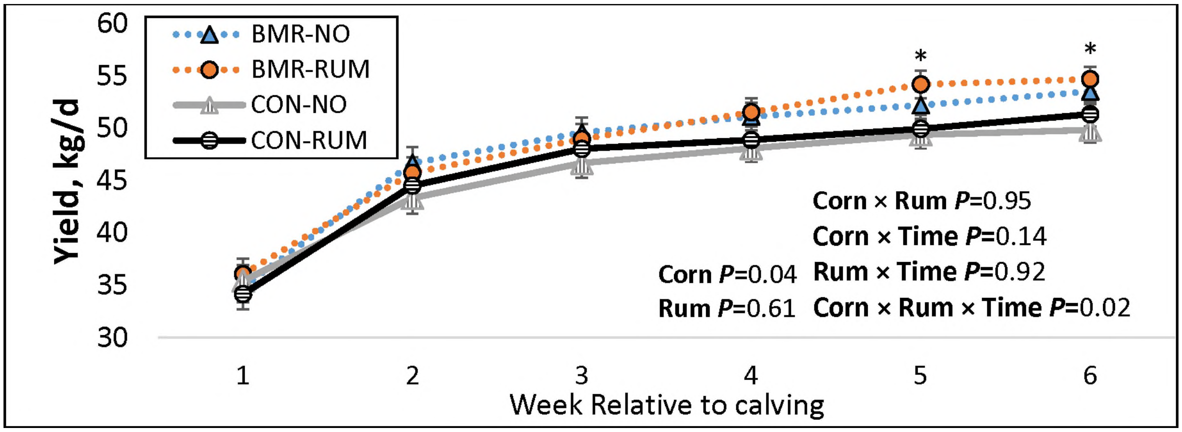

Figure 4. Milk yield by week relative to calving for all treatment groups.

Table 6. Prepartum and postpartum NEFA and BHBA presented as geometric means with back transformed 95% confidence limits.

	Corn		Rumensin		*P*-Value		
Item	**CON**	**BMR**	**NO**	**RUM**	**Corn**	**Rum**	**C×T**[1]
Prepartum							
NEFA, μEq/L	110.6 101.0-121.3	94.8 86.2-104.2	99.3 90.4-109.1	105.6 96.3-115.8	0.02	0.35	0.05
BHBA, mmol/L	0.72 0.68-0.77	0.70 0.66-0.75	0.75 0.70-0.79	0.68 0.64-0.72	0.62	0.04	0.53
Postpartum							
NEFA, μEq/L	458.9 415.7-506.7	369.1 334.2-407.7	440.0 398.4-486.0	385.0 348.7-425.0	<0.01	0.06	0.48
BHBA, mmol/L	1.22 1.10-1.35	1.00 0.90-1.11	1.21 1.10-1.34	1.00 0.91-1.11	<0.01	0.01	<0.01

[1]Interaction of Corn × time, no other interactions for these variables were significant.

Cows fed BMR corn silage performed better overall than cows fed conventional corn silage through the transition period. Higher intakes prepartum, as well as higher yield and more favorable circulating blood metabolites in the postpartum period would suggest these cows were in a more positive energy balance than cows fed CON corn silage, likely due to the increased digestible fiber. With the greater digestibility, it is likely that microbial yield was greater, thus cows fed BMR also had greater MP supply and this could also have a positive impact on milk yield and cow health. Cows fed Rumensin, despite having slightly lower intakes prepartum, had lower circulating BHBA prepartum, as well as lower BHBA and NEFA in the postpartum period. This would again suggest that cows were in better metabolic status. Although we saw minimal statistical interactions between corn silage type and Rumensin, both use different strategies to increase the overall energy availability of the cow. In this vital transition period, these strategies, alone or together, can be key to increasing overall cow health and productivity through their impacts on energy availability and overall energy balance.

CONCLUSIONS

The periparturient period is a pivotal time for dairy cows, and improving energy balance early after calving can greatly impact performance throughout lactation. Data presented here would suggest that $uNDF_{240}$ plays a role in regulating intake early in the fresh period, while feeding a highly digestible fiber ration improves metabolism and performance. Furthermore, use of corn silage hybrids with higher NDF digestibility such as BMR corn silage and addition of monensin improve performance and metabolic status. More research is needed to further investigate the interaction of fiber fractions and carbohydrates and the overall impacts on animal health and productivity. It is likely not just related to energy and there are some indications that MP balance is enhanced through the increased digestibility and intake and this likely has an impact on improving animal productivity. Understanding and utilizing different fiber fractions in fresh cow ration formulation could be key to improving intake, nutrient balance, overall health and milk production.

REFERENCES

Barbano, D. M., C. Melilli, and T. R. Overton. 2014. Advanced use of FTIR spectra of milk for feeding and health management. Pages 105-113 in Proc. Cornell Nutrition Conf., Syracuse, NY.

Bell, A. W. 1995. Regulation of organic nutrient metabolism during transition from late pregnancy to early lactation. J. Anim. Sci. 73:2804-2819.

Cotanch, K. W., R. J. Grant, M. E. Van Amburgh, A. Zotini, M. Fustini, A. Palmonari and A. Formigoni. 2014. Applications of uNDF in ration modeling ahd formulation. Pages 114-131 in Proc. Cornell Nutrition Conf., Syracuse, NY.

Holt, M. S., J. S. Eun, C. R. Thacker, A. J. Young, X. Dai, and K. E. Nestor, Jr. 2013. Effects of feeding brown midrib corn silage with a high dietary concentration of alfalfa hay on lactational performance of Holstein dairy cows for the first 180 days of lactation. J. Dairy Sci. 96:515-523.

Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS System for Mixed Models. SAS Institute Inc., Cary, NC.

McCarthy, M. M., T. Yasui, C. M. Ryan, G. D. Mechor, and T. R. Overton. 2015a. Performance of early-lactation dairy cows as affected by dietary starch and monensin supplementation. J. Dairy Sci. 98:3335-3350.

McCarthy, M. M., T. Yasui, C. M. Ryan, S. H. Pelton, G. D. Mechor, and T. R. Overton. 2015b. Metabolism of early-lactation dairy cows as affected by dietary starch and monensin supplementation. J. Dairy Sci. 98:3351-3365.

McCarthy, M. M., H. M. Dann, and T. R. Overton. 2014. Feeding the fresh cow. Pages 171-183 in Proc. Cornell Nutrition Conf., Syracuse, NY.

Nocek, J. E. 1997. Bovine acidosis: implications on laminitis. J. Dairy Sci. 80:1005-1028.

Ospina, P. A., D. V. Nydam, T. Stokol, and T. R. Overton. 2010. Association between the proportion of sampled transition cows with increased nonesterified fatty acids and beta-hydroxybutyrate and disease incidence, pregnancy rate, and milk production at the herd level. J. Dairy Sci. 93:3595-3601.

Penner, G. B., K. A. Beauchemin, and T. Mutsvangwa. 2007. Severity of ruminal acidosis in primiparous Holstein cows during the periparturient period. J. Dairy Sci. 90:365-375.
Rabelo, E., R. L. Rezende, S. J. Bertics, and R. R. Grummer. 2003. Effects of transition diets varying in dietary energy density on lactation performance and ruminal parameters of dairy cows. J. Dairy Sci. 86:916-925.
Stone, W. C. 2004. Nutritional approaches to minimize subacute ruminal acidosis and laminitis in dairy cattle. J. Dairy Sci. 87(E. Suppl.):E13-E26.
Stone, W. C., L. E. Chase, T. R. Overton, and K. E. Nestor. 2012. Brown midrib corn silage fed during the peripartal period increased intake and resulted in a persistent increase in milk solids yield of Holstein cows. J. Dairy Sci. 95:6665-6676.
Williams, S. E., H. A. Tucker, Y. Koba, R. Suzuki, and H. M. Dann. 2015. Effect of dietary starch content on the occurrence of subacute ruminal acidosis (SARA) and inflammation in fresh dairy cows. J. Dairy Sci. 98(E. Suppl. 2):741-742.