FEEDING THE FRESH COW

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INTRODUCTION

Nutritional management of the transition cow has been a topic of intense research focus for more than 20 years (Grummer, 1995), and during this time many nutritional innovations for the transition cow have been developed and deployed within the dairy industry. Among others, these include decreasing the dietary cation-anion difference of the prepartum diet for management of hypocalcemia, the introduction of "controlled energy" dietary strategies for dry cows to improve the dynamics of energy metabolism and dry matter intake (DMI) during the peripartal period, increased focus on metabolizable protein and amino acid supply to the prepartum cow with some evidence of improved postcalving performance, and the targeted supply of nutrients (e.g., rumen-protected choline) to improve aspects of metabolic health and productivity of transition cows. Furthermore, the importance of management of nonnutritional factors (e.g. stocking density, commingling of multiparous and primiparous cows pre- and postpartum, streamlining grouping changes for transition cows, and mitigating heat stress) is now recognized as a pivotal part of optimizing transition cow health and performance (Cook and Nordlund, 2004; Tao and Dahl, 2013). Collectively, these improvements in both nutritional management of transition cows and management of nonnutritional factors have led to greatly improved health and performance on many dairy farms.

Ironically, the vast majority of transition cow nutritional management research conducted over the past 20+ years has focused almost exclusively on the dry cow. In most studies focused on transition cow nutrition, dietary treatments were imposed during the prepartum period only and cows were fed a common diet during the postcalving period. Fresh cow rations are common in the dairy industry, although often they are modest variations of the high cow ration, perhaps with slightly higher fiber content and/or the inclusion of modest amounts (1.5 lb or less) of straw or hay, lower starch content, additional rumen undegradable protein, increased amounts of supplemental fat, or targeted inclusion of other nutrients or additives (e.g., rumen-protected choline, additional yeast or yeast culture, additional monensin). Success of these strategies was gauged largely at the farm level, because until recently very few controlled research studies examined these factors in the ration fed during the immediate postcalving period. During the past several years, there has been a surge of research interest in the postpartum diet, fueled in part by discussions related to carbohydrate formulation of the postpartum diet and potential interactions with DMI (Allen et al., 2009). Our objective in this paper is to review recent research focused on starch and fiber content in ration formulation for the fresh cow and to speculate about potential interactions of dietary factors in rations that may lead to varying outcomes at the farm level.

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TO STARCH, OR NOT TO STARCH?

Optimizing DMI during the postpartum period is particularly important to provide sufficient energy to support milk production as well as maintain health and support the return of reproductive capacity. Because of increased demand for glucose to synthesize lactose, liver glucose production nearly doubles within 11 days after calving compared to prepartum glucose output (Reynolds et al., 2003). Propionate that is produced via fermentation of starch in the rumen is the main precursor for liver glucose production (Drackley et al., 2001). Although there is a large increase in the liver's utilization of lactate, glycerol, and the glucogenic amino acids postpartum, propionate remains quantitatively the greatest contributor to liver gluconeogenesis at about 60% of precursor supply (Reynolds et al., 2003). Because of this increased demand for glucose postpartum, the liver should have the capacity to direct any additional propionate supply towards glucose synthesis during this early postpartum period (Drackley et al., 2001).

Allen et al. (2009) and Allen and Piantoni (2013) proposed that liver energy status is a major regulator of DMI in dairy cows. Their premise is that when oxidative fuel metabolism (propionate and nonesterified fatty acids (NEFA)) by the liver exceeds the liver's energy requirements, the brain is signaled to reduce DMI. This hepatic oxidation theory would suggest that feeding diets that would increase propionate supply (e.g. greater amounts or fermentability of starch, addition of monensin) during early lactation would decrease DMI via this liver signaling mechanism. If the hepatic oxidation theory applies in this manner to the early lactation period, then reducing the dietary starch content during this period would likely increase DMI by reducing propionate production in the rumen and decreasing the hypophagic effect from propionate oxidation (Allen et al., 2009).

Collectively, our research groups have completed three experiments evaluating starch content of the postpartum diet (Dann and Nelson, 2011; Williams et al., 2015) and starch content of the postpartum diet and monensin supplementation throughout the periparturient period (McCarthy et al., 2015a, 2015b). Dann and Nelson (2011) fed 72 multiparous Holstein cows a controlled energy diet during a shortened (40-d) dry period and then one of three dietary starch regimes during early lactation – a low starch (21.0% starch) diet for the first 91 d postpartum (L), a medium starch (23.2% starch) diet for the first 21 d postpartum followed by a high starch (25.5% starch) diet through 91 d postpartum (MH), and a high starch diet (25.5% starch) for the first 91 d postpartum (H). Sources of starch among diets were primarily conventional, kernel-processed corn silage and dry corn meal; the differences in starch content across diets were achieved by replacing corn meal with soybean hulls and wheat middlings.

In this study, cows fed H throughout the trial period tended to have lower DMI for the first 13 wk postpartum than cows fed L (23.7 vs. 25.2 kg/d); cows fed MH had intermediate DMI (24.9 kg/d). Cows fed MH had higher milk yield than cows fed H (49.9 vs. 44.2 kg/d); cows fed L averaged 47.9 kg/d of milk. Overall, performance of cows in this study was best when fed MH rather than either L or H beginning at calving.

McCarthy et al. (2015a, 2015b) fed primiparous (n = 21) and multiparous (n = 49) Holstein cows diets containing either 26.2% or 21.5% starch from calving through d 21 postpartum; beginning on d 22 postpartum all cows were fed the diet containing 26.2% starch through d 63 postpartum. Starch sources were predominantly brown midrib corn silage and dry corn meal; the overall starch content was varied by replacing corn meal with citrus pulp and soybean hulls. Cows were also fed either 0 or 400 mg/d of monensin beginning 21 d before expected calving and either 0 or 450 mg/d of monensin beginning at calving and continuing through d 63 postpartum. Although there were no overall effects of starch level in the diet on milk yield, a treatment by week interaction existed such that cows fed the higher starch diet had a faster rate of increase in milk yield postcalving. A similar interaction of starch level and week for DMI suggested that cows fed the higher starch diet increased DMI faster during the postpartum period. Cows fed monensin had higher postpartum DMI and milk yield, regardless of starch level in the postpartum diet. Furthermore, cows fed higher starch had lower NEFA and BHBA concentrations postpartum; monensin did not affect plasma NEFA but decreased plasma BHBA concentrations.

The Miner and Cornell studies suggest apparently opposite responses to feeding low- and high-starch diets during the fresh period. A comparison of the low- and high-starch fresh diets between the two studies (Table 1) suggests that the overall starch levels and CNCPS (v. 6.1) predicted levels of fermentable starch (% of DM and % of total fermentable carbohydrate), and total fermentable carbohydrate (% of DM) were quite similar between the low and high starch diets in the two studies. The major apparent difference between the two studies relates to the diet fed during the prepartum period. In the Miner study, cows were fed a typical low starch (13.5% of DM), controlled energy diet for the entire 40-d dry period whereas in the Cornell study, cows were fed a moderate starch close up diet (17.4% of DM). We speculate that the large differences in starch levels and fermentability between the prepartum diet and the high starch postpartum diet in the Miner study compromised the transition of cows onto the high starch postpartum diet in that study. Likewise, we speculate that feeding the higher starch prepartum diet to cows in the Cornell study facilitated their transition onto the higher starch postpartum diet. However, we also noted that intake (kg/d and % of body weight) of starch and NDF was lower in the Cornell study than the Miner study during the first 3 and 9 weeks of lactation. Given the lower NDF digestibility (NDFD) of the low and high starch diets used in the Cornell study (~56% NDFD at 30-h) compared with the Miner study (58 and 54% NDFD at 24-h for the low and high starch diets, respectively), it is possible that the cows fed both the low and high starch diets at Cornell containing 11.5% of DM as straw were limited by gut fill during the first 3 wk of lactation with NDF intake of <1.1% of body weight. This reinforces the need to use highly digestible fiber sources when lower starch diets are fed whether it is high cows or fresh cows. Both studies used a “21-d fresh period”. However, the optimal duration of feeding a fresh diet is unknown and it most likely varies among cows given differences in rate of increase in DMI and milk production.

Studies in the literature that offer the opportunity to examine interactions of prepartum and postpartum diets are limited. Rabelo et al. (2003; 2005) fed cows and first calf heifers either low or high energy diets prepartum followed by either low or high energy diets postpartum until d 20 postcalving, then all cows were fed the high energy diet through d 70 postcalving. The prepartum diets were based upon alfalfa silage, corn silage, a comparatively small proportion (10 to 15% of DM) of chopped straw, and grain mixes consisting predominantly of corn meal. Prepartum, the "low" energy diet contained 39.7% NDF and 38.2% NFC and the "high" energy diet contained 32.2% NDF and 44.6% NFC. The postcalving diets were based upon alfalfa silage and corn silage, and grain mixes consisting predominantly of corn meal – the "low" energy diet contained 29.9% NDF and 41.4% NFC; the "high" energy diet contained 24.9% NDF and 47.2% NFC. Cows fed the high energy diet prepartum had higher prepartum DMI and no difference in postpartum DMI, and cows fed the high energy diet postpartum tended to have higher DMI and had higher energy intake from d 1 to 30 postpartum; overall effects of treatment from d 1 to 70 postcalving were not significant. Rates of increase of milk production were greater for cows fed high energy diets postcalving, and plasma concentrations of BHBA were substantially lower for cows fed the high energy postcalving diet when measured on d 7 and 21 postcalving. Interactions of prepartum and postpartum diets were largely not significant for response variables in this experiment; however, we note that both prepartum diets were comparatively high in NFC by current standards and the high energy postpartum diet was higher in NFC than current diets – starch values for diets were not reported in this study.

Table 1. Comparison of prepartum and postpartum rations from Miner and Cornell studies focused on varying starch levels in the fresh diet (Dann, personal communication).

Study & Group	Starch, %DM	Ferm.[1] starch, %DM	Ferm. starch, % Total ferm. CHO[2]	Total ferm. CHO, %DM
Miner (Dann and Nelson, 2011)				
Dry	13.5	11.5	29.7	39.4
Low fresh	21.0	16.8	40.1	42.4
High fresh	25.5	20.2	50.3	44.1
Cornell (McCarthy et al., 2015a,b)				
Close-up	17.4	15.3	36.3	42.2
Low fresh	21.5	16.8	42.1	39.9
High fresh	26.2	21.5	53.2	40.4

[1] Ferm = fermentable

[2] CHO = carbohydrate

Most of the early discussion surrounding the importance of prepartum diet on ruminal adaptation to postpartum diet focused on the potential importance of diet on ruminal papillae development (Dirksen et al., 1985). However, subsequent research (Andersen et al., 1999; Reynolds et al., 2004) did not support the idea that changes in ruminal papillae and mucosa were important factors in ruminal adaptations during the transition period under typical dietary strategies. Of course, the adaptation of the ruminal microbiota to lactation would be a potentially important adaptation as well as overall adaptation of rumen fermentation to postpartum diets. Research conducted by Penner et al. (2007) suggested that cows have a dramatic increase in the amount of time with a ruminal pH between 5.5 and 5.8 (categorized as mild acidosis in their study) between d 2 and 5 postcalving; in their experiment ruminal acidosis was much lower during the dry period as well as at d 17, 37, and 58 postcalving. Interestingly, varying the forage to concentrate ratio of the prepartum diet did not affect postpartum incidence or severity of ruminal acidosis.

Recently, Williams et al. (2015) examined the effects of starch content of the postpartum ration on subacute ruminal acidosis and the acute phase response in 16 multparous Holstein cows. Cows were fed a close-up diet based upon conventional corn silage, haycrop silage, straw, and a grain mix (TMR contained 43.6% NDF and 15.5% starch). The postpartum treatment diets both contained the same proportions of conventional corn silage (28.3% of DM), haycrop silage (21.7% of DM) and straw (2.0% of DM); the high starch (27.2% of DM) and low starch (21.3% of DM) diets had different proportions of corn meal and nonforage fiber sources (soybean hulls and wheat middlings). Cows fed the high starch diet had lower rumen pH and increased time with ruminal pH < 5.8 during the first 3 weeks after calving. Also, cows fed the high starch diet hadincreased concentrations of haptoglobin and serum amyloid A in serum with the greatest differences occurring in the first 2 weeks. These data suggest that higher postpartum starch levels contribute to lower rumen pH and increased inflammation during the fresh period.

WHAT ABOUT FIBER?

Although there has been substantial discussion within academia and the industry over the past several years regarding starch levels in the postcalving diet, there has been very little discussion regarding fiber levels in the postcalving diet. In particular, we are interested in the fiber fraction that contributes toward rumen mat formation and proper rumen function that typically has been referred to as physically effective NDF(peNDF), although the more recent focus on undigestible NDF (uNDF) intrigues us as a more objective measure of fiber that may contribute to rumen structure and proper rumen function.

Our interest in fiber levels in postpartum diets stems specifically from our experience in the early stages of the experiment described above (McCarthy et al., 2015a) that caused us to essentially restart the experiment. The first cows calving onto the experiment developed a number of health issues, including quite strong clinical ketosis beginning 3 to 7 d postcalving and a high proportion of DA, particularly on the high starch treatment (See treatments HSLF and LSLF in Table 2). We identified that the NDF levels of both the BMR corn silage and legume silage used in the postpartum diets were lower than those used for formulation. We decided to increase the inclusion rate of straw in the diet, replacing an equal amount of BMR corn silage. We kept the inclusion rates of the legume silage and the grain mix inclusion rates and formulation the same. Ingredient and chemical composition of the prepartum diet and the high starch and low starch diets before the change in straw and BMR corn silage (HSLF and LSLF) and after the change in straw and BMR corn silage (HSHF and HSLF) are presented in Table 3. These changes resulted in substantially increased NDF and $uNDF_{240}$ content of the postpartum diets following this change.

The effects of this change on postpartum health outcomes were immediate and lasted for the duration of the re-started experiment. Prior to the change, 5 out of 17 cows had clinical ketosis and 6 out of 17 cows had DAs. After the change, there were no DAs and 10 cases of clinical ketosis out of 77 cows calved (Table 2).

Prepartum DMI and intakes of $uNDF_{240}$ (both lb/d and expressed as a % of BW) are presented in Table 4. Although means are reported by treatment and statistical analysis conducted, we remind the reader that all cows were fed the same prepartum ration throughout the study and no changes were made at the time the changes were made to the postpartum ration. Thus, the general lack of treatment differences is logical. Multiparous cows did consume less $uNDF_{240}$ lb/d (~4.5 lb/d vs. ~ 5.1 lb/d; $P < 0.02$) after the ration change. We suspect that this related to either changes in the conventional corn silage or seasonal/heat effects on overall DMI as the experiment was started in early April 2012, the change was made in early May, and cows calved throughout the summer. Interestingly, multiparous cows consumed about 0.30% of their BW as $uNDF_{240}$ and primiparous cows consumed 0.20 to 0.22% of their BW as $uNDF_{240}$ during the prepartum period.

Postpartum DMI, intakes of $uNDF_{240}$, and milk yield are presented in Table 5. Following the partial replacement of BMR corn silage with wheat straw, overall DMI and intakes of $uNDF_{240}$ (both lb/d and as a % of BW) were increased. Before the ration change, multiparous cows consumed about 0.30% of their BW as $uNDF_{240}$ and primiparous cows consumed about 0.24% of their BW as $uNDF_{240}$. After the ration change, cows consumed about 0.38% of their BW as $uNDF_{240}$ and primiparous cows consumed about 0.31% of their BW as $uNDF_{240}$.

Although the ration change increased DMI and $uNDF_{240}$ intakes despite greater straw inclusion in the ration, of interest are the interactions between starch level and fiber level on postpartum DMI and milk yield. Cows fed the high starch ration concurrent with high fiber (after ration change) had the highest DMI; DMI of cows fed the low starch diet with either high or low fiber were intermediate, and DMI for cows fed the high starch diet with low fiber (before diet change) was the lowest of the four groups. This interaction is particularly evident in Figure 1 and is consistent with the higher overall incidence of clinical ketosis and DA for cows fed the high starch diet prior to the diet change.

We acknowledge that we need to interpret the direct comparisons of performance before and after the ration change with caution, given confounding with other factors (e.g., season, environment, other forage or feed changes); however, we interpret the results of this case study as evidence that starch level of the postpartum diet may depend in part on the fiber formulation in the ration. In situations where forage NDF is low to marginal, likely the best strategy is a lower (or less fermentable) starch ration. However, in situations where forage NDF content in the ration is adequate, and perhaps at levels higher than most nutritionists typically consider, higher starch rations may yield better overall results. Currently, we are conducting an experiment (Williams et al., personal communication) designed to evaluate this hypothesis and determine the effects of varying dietary $uNDF_{240}$ level in the postpartum ration on postpartum performance, metabolism, and acute phase response in cows.

Table 2. Health events for cows fed either high or low starch diets for the first 3 wk postpartum before and after postpartum ration changes.

	Postpartum ration[1]				Parity		*P*-values[2]		
Item[3]	HSLF	LSLF	HSHF	LSHF	Primi	Multi	S	F	P
Multiparous, n	3	8	27	28					
Primiparous, n	4	2	11	11					
Clinical ketosis[3]	4	1	4	6	6	9	0.23	0.05	0.14
DA[4]	4	2	0	0	4	2	0.22	<0.001	0.06
RP[5]	1	2	2	1	3	3	0.32	0.05	0.20
Total disorders	9	5	6	7					

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[1] HSLF = high starch, low fiber (pre-change); LSLF = low starch, low fiber (post-change); HSHF = high starch, high fiber (post change); LSHF = low starch, high fiber (post-change).

[2] S = effect of starch; F = effect of fiber; P = effect of parity.

[3] Clinical ketosis defined as rapidly decreased milk production and DMI and blood BHBA ≥ 2.6 mmol/L using Precision Xtra, displaced abomasum by auscultation

[4] Displaced abomasium diagnosed by auscultation.

[5] Placenta retained for ≥ 24 h postcalving.

Table 3. Ingredient and chemical composition of diets (± SD[1]) before and after postpartum ration changes (DM basis)

		Postpartum[2]			
Item	Prepartum	HSLF	LSLF	HSHF	LSHF
Ingredient (% of DM)					
Corn silage, conv.	42.1	---	---	---	---
BMR corn silage	---	46.1	46.1	38.5	38.5
Wheat straw	21.2	3.84	3.84	11.5	11.5
Legume silage	---	9.62	9.62	9.62	9.62
Corn meal, fine	4.28	21.0	10.3	21.0	10.3
Citrus pulp	7.23	1.01	7.15	1.01	7.15
Corn germ meal	---	2.52	5.56	2.52	5.56
Soybean hulls	7.08	---	3.58	---	3.58
Soybean meal	5.27	5.87	3.86	5.87	3.86
Canola meal	4.63	2.73	2.08	2.73	2.08
Blood meal	1.05	1.94	1.93	1.94	1.93
Expeller soy	1.78	1.70	2.34	1.70	2.34
Bypass fat	---	0.77	0.96	0.77	0.96
Anionic suppl.	1.33	---	---	---	---
Sodium bicarbonate	---	0.86	0.85	0.86	0.85
Minerals/vitamins	3.35	1.99	1.72	1.99	1.72
Chemical					
CP, %	13.0 ± 0.8	16.5	15.3	15.5 ± 1.2	15.4 ± 0.8
ADF, %	28.2 ± 1.2	17.7	22.3	22.7 ± 1.2	25.2 ± 1.2
NDF, %	42.9 ± 2.0	26.4	31.5	34.3 ± 1.5	36.9 ± 1.5
Sugar, %	4.9 ± 0.8	3.1	3.9	3.5 ± 0.6	4.5 ± 0.4
Starch, %	17.4 ± 1.2	28.3	22.0	26.2 ± 1.2	21.5 ± 1.0
Fat, %	2.6 ± 0.2	3.2	3.1	4.0 ± 0.2	2.2 ± 0.6
uNDF_{240},[3] % of DM	14.9	7.7	8.9	10.5	10.9

[1] Chemcial composition was analyzed on 4-wk composite samples (n = 1 for HSLF, n = 1 for LSLF, n = 7 for HSHF, and n = 6 for LSHF).

[2] HSLF = high starch, low fiber (pre-change); LSLF = low starch, low fiber (post-change); HSHF = high starch, high fiber (post change); LSHF = low starch, high fiber (post-change).

[3] Determined using wet chemistry methods on a single composite sample from each diet (Cumberland Valley Analytical Services, Hagerstown, MD)

Table 4. Prepartum DMI and $uNDF_{240}$ intakes for primiparous and multiparous animals fed high starch (HS) and low starch (LS) diets before (LF) and after (HF) partial replacement of BMR corn silage with straw in postpartum diets.

	Postpartum diet					P values		
Item	HSLF	LSLF	HSHF	LSHF	SEM	Starch	Fiber	Starch x Fiber
Prepartum DMI, lb/d								
Overall	28.0	28.7	29.5	28.0	1.7	0.74	0.71	0.38
Multiparous	35.0	34.5	33.0	31.4	2.8	0.54	0.12	0.75
Primiparous	19.7	19.9	21.9	20.0	1.3	0.76	0.60	0.64
$uNDF_{240}$ intake, lb/d								
Overall	4.01	4.01	4.17	3.97	0.20	0.56	0.73	0.56
Multiparous	5.11	5.05	4.63	4.41	0.37	0.54	0.02	0.74
Primiparous	2.84	2.76	3.00	2.84	0.26	0.55	0.55	0.84
$uNDF_{240}$ intake, % of BW								
Overall	0.26	0.27	0.27	0.26	0.01	0.92	0.73	0.36
Multiparous	0.32	0.31	0.30	0.29	0.01	0.59	0.08	0.81
Primiparous	0.20	0.20	0.22	0.21	0.02	0.65	0.36	0.87

Table 5. Postpartum DMI, uNDF$_{240}$ intakes, and milk yield for primiparous and multiparous animals fed high starch (HS) and low starch (LS) diets before (LF) and after (HF) partial replacement of BMR corn silage with straw in postpartum diets.

	Postpartum diet					P values		
Item	HSLF	LSLF	HSHF	LSHF	SEM	Starch	Fiber	Starch x Fiber
Postpartum DMI, lb/d								
Overall	39.2	43.8	47.3	44.4	2.4	0.63	0.01	0.03
Multiparous	43.9	53.0	51.3	48.3	3.1	0.11	0.48	0.002
Primiparous	32.5	30.2	36.4	34.5	1.3	0.12	0.005	0.89
uNDF$_{240}$ intake, lb/d								
Overall	3.35	3.68	4.98	4.74	0.24	0.81	<0.001	0.08
Multiparous	3.79	4.70	5.38	5.11	0.20	0.11	<0.001	0.004
Primiparous	2.82	2.73	3.81	3.66	0.13	0.32	<0.001	0.82
uNDF240 intake, % of BW								
Overall	0.26	0.28	0.37	0.36	0.01	0.95	<0.001	0.10
Multiparous	0.29	0.31	0.39	0.38	0.02	0.80	<0.001	0.13
Primiparous	0.24	0.24	0.32	0.3	0.01	0.58	<0.001	0.36
Milk yield, lb/d								
Overall	76.2	90.0	86.4	83.5	6.8	0.26	0.70	0.09
Multiparous	97.0	98.1	94.4	91.3	8.0	0.84	0.34	0.66
Primiparous	66.1	61.0	65.5	67.0	5.7	0.66	0.50	0.41

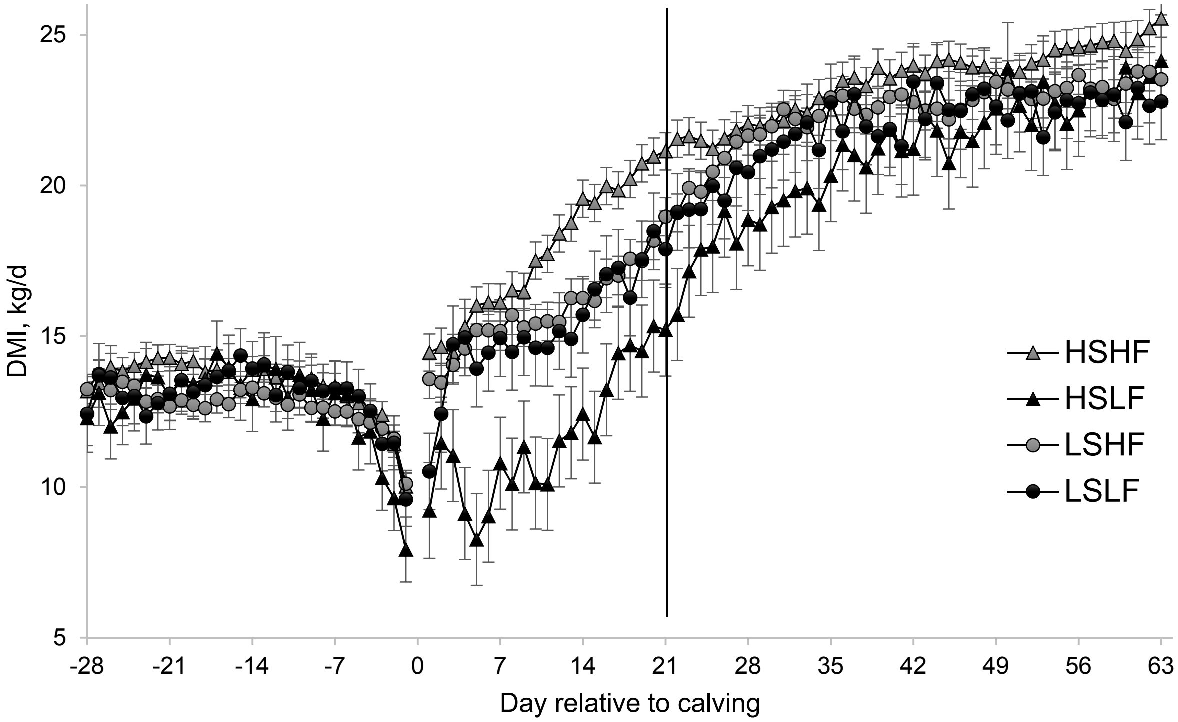

Figure 1. Dry matter intakes (DMI) of cows fed high starch (HS) or low starch (LS) before (LF) and after (HF) a ration change to partially replace BMR corn silage with straw and subsequently increase the NDF and $uNDF_{240}$ content of both rations. Treatment rations were fed from 0 - 21 DIM; at 22 DIM all cows were switched to the HS diet.

CONCLUSIONS

Studies conducted during the past several years are yielding important information regarding nutritional approaches for the cow during the immediate postpartum period, although we still have much to learn in the area of fresh cow nutrition. Although some studies suggest that feeding higher starch rations in the immediate postpartum period may improve metabolism and performance during early lactation, other studies suggest that feeding lower starch rations during the immediate postpartum period lead to better performance. Comparison of some of these studies suggests that feeding higher starch rations before calving may lead to better ability of cows to tolerate a higher starch ration after calving. Furthermore, case study work as part of an experiment in our group suggests that peNDF or $uNDF_{240}$ content of the postpartum is important to consider in ration formulation, and that nutritionists should consider feeding higher levels of straw or other feeds with high $uNDF_{240}$ content than they have typically feed. Furthermore, the optimum starch level for formulation may depend upon the peNDF or $uNDF_{240}$ content of the postpartum diet.

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