Nutritional Management of Fresh Cows: Helping for Smooth Take Off

Masahito Oba

Dept. of Agricultural, Food and Nutritional Science, University of Alberta
Email: masahito.oba@ualberta.ca

▪ Take Home Messages

- It is recommended to prepare a different TMR for fresh cows, if possible, to address their specific needs.
- Animal responses to supplemental fat vary depending on stage of lactation; more variable and sometimes negative during the fresh period compared with peak lactation. Fresh cows, mobilizing their fat reserves, have limited capacity to metabolize additional fatty acids supplied from diets. Fat supplementation requires caution during the fresh period.
- Increasing dietary starch content does not always increase milk production of fresh cows. Cows fed high-starch close-up diets may respond better to high starch diets postpartum, but cows fed low-starch controlled-energy diets before calving likely respond better to low starch diets during the fresh period. The fresh period is a part of the calving transition period, and optimum postpartum nutritional management is likely affected by nutritional management before calving.
- Cows with sub-acute rumen acidosis alter their feed preference, and attempt to consume more long forage. We should provide fresh cows with top-dressed long hay in addition to TMR to allow them to consume more physically effective fibre, as needed, to attenuate rumen acidosis.
- Increasing metabolizable protein supply in the fresh diets may lead to greater milk production.
- Feeding *Saccharomyces cerevisiae* fermentation products may increase DMI during the peripaturient period and improve health of fresh cows.

WCDS Advances in Dairy Technology (2018) Volume 30: 117-129

Introduction

The calving transition period can be defined as a period from 3 weeks prior to calving to 3 weeks after calving. Nutritional management during the calving transition period is critically important as it affects health, milk production, and reproductive performance of dairy cows. Nutritional management during the pre-partum phase of this transition period (i.e., close-up period) has been extensively studied over the last few decades, but only limited data exist for the nutritional management of the post-partum phase of the transition period (i.e., fresh period). As fresh cows usually experience a negative energy balance, some nutritionists try to maximize their energy intake by increasing the energy density of diets, but this effort does not necessarily increase energy intake if DMI is reduced. For example, feeding high starch diets or high fat diets increases energy density of diets, but their effects on energy intake, energy balance, and overall productivity of dairy cows are not very consistent. The objectives of this paper are to review several recent research publications that evaluated the nutritional management of fresh cows and to discuss how to optimize their performance.

Should We Feed High Fat Diets to Fresh Cows?

Generally speaking, fat supplementation is a useful approach to increase milk production and improve reproductive performance of high producing dairy cows, but it is important to note that high fat diets do not always work positively for fresh cows. Animal responses to high fat diets during the fresh period are not consistent in the literature. Sklan et al. (1991) fed Ca salts of fatty acids (48.1% palmitic acid, 4.4% stearic acid, 40.2% oleic acid, and 7.4% linoleic acid) during the first 120 d after calving and reported positive effects on overall milk production and reproductive performance. However, the fat supplementation increased BW loss during the first few weeks after calving.

Beam and Butler (1998) fed prilled fatty acids (Energy Booster-100®; Milk Specialties Co., Dundee, IL) to increase dietary fat content from 4.8 to 7.0%. They found that cows fed the high fat diet decreased DMI during the first 4 week after calving (15.5 vs. 17.3 vs. kg/d), and reported a tendency for diet x week interaction where cows fed the high fat diet decreased milk yield during the first 3 week after calving, but increased milk yield starting 5 week after calving.

Piantoni et al. (2015) fed saturated fatty acids (46.2% stearic acid and 37.0% palmitic acid) to fresh cows from d 1 to 29 after calving, and reported that the fat supplementation increased DMI (23.6 vs. 22.2 kg/d) and decreased BW loss (-96 vs. -118 kg). However, in their study, the diet high in saturated free fatty acids tended to decrease milk yield (46.6 vs 49.7 kg/d).

More recently, de Souza and Lock (2017) fed a high fat diet supplemented with palmitic acid either during the fresh period (until 24 days in milk) or peak period (25 to 67 days in milk). The high fat diet did not affect milk yield and decreased BW (668 vs. 709 kg) in the fresh period, but increased milk yield (58.0 vs. 54.6 kg/d) without affecting BW during peak lactation.

These studies collectively indicate that animal responses to high fat diets are highly variable during the fresh period, and less positive – or sometimes even negative – compared to the peak lactation period. Variable animal responses reported in the literature are partly attributed to different type of fatty acids evaluated in the studies, but it is apparent that fresh cows respond to fat supplementation differently than cows in peak lactation.

A variable lipolytic state is a possible reason for inconsistent animal responses to fat supplementation during the fresh period. Cows have limited capacity to metabolize fat, and supplemental fat during the fresh period may exceed the capability to metabolize fat if cows excessively mobilize their body reserve (Palmquist, 1994). Some cows may lose more body condition than others depending on cow comfort, management during the transition period, and BCS at calving. Feeding high fat diets is not recommended in herds where cows excessively lose body condition because fat supplementation may delay recovery of DMI, thereby making the situation even worse. However, in dairies with good transition management, where the postpartum increase in feed intake is smooth, cows do not mobilize their own fat excessively and as such they have the metabolic capacity to deal with fat supplied from diets. In such herds, it is likely that animals respond to fat supplementation more positively and sooner after calving.

▪ Should We Feed High Starch Diets to Fresh Cows?

Another approach to increase diet energy density is to increase starch content of diets. Increasing dietary starch content generally improves the energy status of animals indicated by blood metabolites. Penner and Oba (2009) and McCarthy et al. (2015b) reported that increasing starch content of fresh diets increased blood glucose concentration and decreased plasma concentrations of NEFA and BHB. However, it is noteworthy that animal responses to high starch diets in milk production have not been consistent in the literature.

McCarthy et al. (2015a) compared the effects of feeding TMR differing in dietary starch content during the fresh period (26.2 vs. 21.5%) and reported starch content x week interactions for DMI and milk yield, indicating that cows fed the high starch diet had faster increase in DMI (15.6 vs. 14.8 kg/d) and milk yield (31.0 vs. 29.8 kg/d) during the first 3 weeks after calving. In addition, cows fed the high starch diet decreased BCS to a lesser extent (-0.21 vs. -0.33) and experienced less negative energy balance (-6.8 vs. -11.8 Mcal/d) during the fresh period compared with those fed the low starch diet.

Similarly, Piantoni et al. (2015) compared fresh diets differing in dietary forage NDF content, which also differed in dietary starch content (24.0 vs. 17.5%), and reported that cows fed the high-starch fresh diets increased DMI compared with those fed the low starch diet (23.9 vs. 21.9 kg/d), although milk yield was not affected.

Contrarily, a recent Dutch study (Dieho et al., 2016) reported that milk yield was greater for cows fed low starch diets during the fresh period. Dieho et al. (2016) evaluated two different rates of increase in concentrate allowance after calving. After cows were fed concentrate at 0.9 kg/d for 3 d immediately after calving, they were assigned to treatment of either rapid (RAP; a 1.0-kg increase per day over a 10-d period to reach the maximum allowance of 10.9 kg/d on d 13) or gradual increase in concentrate allowance (GRAD; a 0.25-kg increase per day over a 40-d period to reach the maximum allowance of 10.9 kg/d on d 43). The starch contents were 13.9 and 24.8%, respectively, for basal TMR and concentrate. Although dietary starch contents have changed throughout the experimental period depending on the treatments and actual intake of the basal TMR, cows on the RAP treatment were obviously fed more starch during the fresh period. Although total DMI was not affected by treatment, milk yield tended to be lower for RAP than GRAD treatment (i.e., for cows fed high starch diets; 33.2 vs. 37.6 kg/d).

Dieho et al. (2016) reported negative responses to high-starch fresh diets, while McCarthy et al. (2015a) and Piantoni et al. (2015) reported positive responses to high-starch fresh diets. These discrepancies may be attributed to different starch contents of close-up diets that animals were fed before calving. Dann (2016) made similar observations as Dieho et al. (2016) and speculated that cows fed high-starch close-up diets would respond better to high-starch fresh diets while cows fed low-starch controlled-energy diets before calving would respond better to low-starch fresh diets. Consistent with this speculation, in the studies of McCarthy et al. (2015a) and Piantoni et al. (2015), starch contents of close-up diets were relatively high (17.4 and 18.1%, respectively) while Dieho et al. (2016) fed a low-starch close-up diet (9.0%). Fresh cows might need to be metabolically ready, by being fed high-starch close-up diets, to benefit from highly fermentable diets after calving.

More and more dairies are feeding controlled-energy diets before calving (feeding straw at approximately 30% of dietary DM) to avoid excess energy intake before calving and reduce metabolic complications after calving (Mann et al., 2015). It is important to check what diet is being fed to close-up cows when the nutritional management of fresh cows is discussed. The optimum starch content of fresh diets is likely affected by the starch content of close-up diets, and high starch diets may not always work during the fresh period. The fresh period should not be considered as a stand-alone period, but rather as a part of the whole calving transition period.

Several other studies conducted at U of A evaluated the effects of starch content of fresh diets. Penner and Oba (2009) replaced corn grain with sucrose in a diet for fresh cows to increase dietary sugar content from 4.5 to 8.7% and to decrease dietary starch content from 20.6 to 18.5%. They reported that the high sugar diet (i.e., low starch diet) increased DMI (18.3 vs. 17.2 kg/d) and tended to increase mean rumen pH (6.21 vs. 6.06) and milk fat yield (1.44 vs. 1.35 kg/d), although milk yield was not affected by treatment. Dyck et al. (2011) replaced a part of barley silage with corn starch in a diet for cows in early lactation (from calving to 70 days in milk) to increase dietary starch content from 23.3 to 26.7%, but reported that the high starch diet did not increase DMI, milk production, or energy balance. Sun and Oba (2014) fed high vs. low starch diets (29.2 vs. 19.1%; rolled barley grain was replaced by wheat DDGS for the low starch diet) to cows in early lactation (from calving to 12 weeks in lactation) and reported no difference in milk yield, even with a 10%-unit difference in dietary starch content.

Both Penner and Oba (2009) and Sun and Oba (2014) reported that energy balance, indicated by plasma NEFA concentration, was better for cows fed the high starch diets, but that cows fed the high starch diets did not increase milk yield. These observations indicate that high starch diets may not always increase milk yield of fresh cows, and other energy sources, such as sugar or digestible fibre, are at least as effective as starch to maintain milk production during the fresh period. Interestingly, both Dyck et al. (2011) and Subramaniam et al. (2016) reported that high starch diets increased the incidence of multiple ovulations compared with those fed the low starch diets, although dietary starch content did not affect overall reproductive performance in their studies.

▪ Should We Feed More Physically Effective Fibre to Fresh Cows?

It is also important to note that fresh cows have a greater risk of sub-acute rumen acidosis (SARA; Penner et al., 2007), and appropriate management actions should be taken to reduce the severity of SARA. Keunen et al. (2002) reported that cows with SARA altered feed preference when given a choice of feeds; they decreased intake of alfalfa pellet and increased intake of long alfalfa hay, which provides more effective fibre to stimulate chewing and salivary buffer secretion, thereby attenuating SARA. However, Keunen et al. (2003) reported in a follow-up study that SARA cows did not increase their intake of sodium bicarbonate, indicating that long hay is a preferred feedstuff for cows experiencing SARA.

Maulfair et al. (2013) made similar observations. They prepared a TMR with long-particle forage and dry cracked corn (slowly-fermenting starch) and a TMR with short-particle forage and fine ground corn (faster-fermenting starch). They offered both of them side by side to animals before and after SARA was induced. Although animals preferred the TMR with short-particle forage during the baseline period, they altered feed preference after SARA was induced. The relative intake of TMR containing long-particle forage increased on the day of SARA and the following day (i.e., recovery day), then decreased to the baseline level. These observations indicate that cows with SARA attempt to increase consumption of long-particle forage to mitigate the severity of SARA.

Considering the greater risk of SARA in fresh cows (Penner et al., 2007), it may be wise to consider formulating a different TMR for fresh cows, and feed less starch and more physically-effective highly-digestible forage fibre. Alternatively, if it is difficult to prepare a different TMR for fresh cows, we should at least consider offering fresh cows top-dressed long hay in addition to a common TMR for lactating cows. This approach allows fresh cows to consume additional hay, as needed, to attenuate SARA that they likely experience after calving.

▪ Should We Feed High Protein Diets to Fresh Cows?

Fresh cows do not only mobilize their fat reserves, but also their protein reserves to support milk production. As such, it is important to consider specific nutrient needs on the protein side as well. Carder and Weiss (2017; Table 1) recently evaluated three diets differing in supply of metabolizable protein (MP) and amino acid profile during the fresh period (d 3 to 23 after calving); MP-allowable milk yield was 25 and 30 kg/d for the low MP diet and the high MP diets, respectively, assuming 17 kg/d of DMI. One of the high MP diets was balanced for the optimum amino acid profile (+AA; containing Met and Lys at 2.60 and 7.20 % of MP, respectively) while the other high MP diet was not (-AA; containing Met and Lys at 1.83 and 6.33 % of MP, respectively). They showed that feeding the high MP diets increased energy-corrected milk yield and decreased plasma concentration of 3-methylhistidine, which is an indicator of muscle protein turnover. Although the long-term carryover effects of reduced muscle protein mobilization on milk production were not observed in their study, these findings suggest that greater MP supply to fresh cows has beneficial effects.

Table 1. Effects of dietary starch content on milk yield of fresh cows (adapted from Carder and Weiss, 2017)

	Low	High MP		P values*	
	MP	- AA	+ AA	MP	AA
DMI, kg/d	17.8	18.0	18.5	NS	NS
Milk yield, kg/d	33.6	34.7	33.2	NS	NS
Milk fat, %	3.80	4.21	4.51	< 0.01	NS
Milk protein, %	3.17	3.17	3.30	NS	0.04
Energy-corrected milk yield, kg/d	35.3	38.6	38.4	0.05	NS
Plasma 3-methylhistidine, µM	5.80	4.50	4.55	0.03	NS

* MP = contrast between low MP diet vs. two high MP diets; AA = contrast between -AA vs. +AA.

■ Recent University of Alberta Study

We recently completed a study evaluating nutritional management during the calving transition at the University of Alberta (Shi et al., unpublished). In this study, we evaluated the effects of supplementing a novel *Saccharomyces cerevisiae* fermentation product (SCFP; NutriTek; Diamond V Mills Inc., Cedar Rapids, IA) during the periparturient period and dietary starch content during the first three weeks immediately after calving. The SCFP was mixed in TMR to provide 19 g/d assuming DMI of 11 and 20 kg/d for prepartum and postpartum cows, respectively. Experimental diets were fed from 4 weeks prior to the expected calving date to 6 weeks after calving. All animals were fed a common basal close-up diet (13.9% starch, 15.3% CP, 1.43 Mcal of NEL/kg DM), and fed either a high starch (28.3% starch, 17.2% CP, 1.64 Mcal of NEL/kg DM) or a low starch diet (22.0% starch, 17.2% CP, 1.61 Mcal of NEL/kg DM) during the first three weeks after calving. All cows were fed the high starch diets from week 4 after calving.

Cows fed the low starch diets had greater milk yield compared with those fed the high starch diets during the first 3 week after calving (34.1 vs. 32.1 kg/d; Table 2). Moreover, they tended to have greater milk yield even after they were switched to the high starch diets (Week 4 to 6 after calving; 42.3 vs. 40.3 kg/d). These are consistent with the findings of Dieho et al. (2016), as discussed in the previous section. It is noteworthy that both Dieho et al. (2016) and the current study fed low-starch controlled-energy diets before calving, and observed greater milk yield in cows fed low starch diets during the fresh period.

Table 2. Effects of starch content of fresh diets and supplementation of a novel *Saccharomyces cerevisiae* fermentation product (SCFP) during the periparturient period on postpartum DMI and milk production

	Low Starch		High Starch		P values		
	CON	SCFP	CON	SCFP	Starch	SCFP	INT
Week 1-3							
DMI, kg/d	16.2	17.2	16.4	17.5	0.57	0.22	0.36
Milk yield, kg/d	34.4	33.8	31.1	33.0	0.05	0.54	0.24
Milk fat, kg/d	1.48	1.61	1.53	1.53	0.73	0.22	0.21
FCM / DMI	2.54	2.51	2.52	2.49	0.79	0.72	0.98
Week 4-6							
DMI, kg/d	20.7	19.9	20.6	19.8	0.77	0.10	0.98
Milk yield, kg/d	42.6	41.9	39.4	41.2	0.09	0.60	0.27
Milk fat, kg/d	1.56	1.66	1.60	1.63	0.92	0.21	0.46
FCM / DMI	2.12	2.29	2.14	2.26	0.91	0.01	0.62

The greater milk yield for cows fed the low-starch fresh diets observed in the recent U of A study cannot be attributed to greater energy intake because DMI and total tract OM digestibility were not affected by dietary starch concentration. In addition, energy status indicated by plasma metabolites was better for cows fed the high starch diets (Table 3). Furthermore, cows fed the low starch diets tended to lose more BCS during the first 3 weeks after calving (-0.42 vs. -0.35 /21d). As such, the reasons for greater milk production for cows fed the low starch diets are not clear; however, cows fed the low starch diets had greater apparent total tract NDF digestibility compared with those fed the high starch diets on d 7 ± 3 after calving (40.7 vs. 35.3%), indicating that the low-starch fresh diets provided more energy from fibre fermentation in the rumen, which can supply energy to animals more consistently over time, and indicate that how energy is supplied might be an important factor affecting productivity of fresh cows. However, further research is warranted to evaluate this speculation.

Table 3. Effects of starch content of fresh diets and supplementation of a novel *Saccharomyces cerevisiae* fermentation product (SCFP) during the periparturient period on plasma metabolite concentrations

	Low Starch		High Starch		P values		
	CON	SCFP	CON	SCFP	Starch	SCFP	INT
d 7 ± 3 after calving							
Glucose, mg/dL	58.5	56.2	61.0	59.6	0.05	0.23	0.75
NEFA, mEq/L	568[a]	423[b]	386[b]	463[ab]	0.16	0.50	0.03
BHB, mg/dL	9.34	8.44	9.23	8.51	0.98	0.20	0.90
d 21 ± 3 after calving							
Glucose, mg/dL	58.2	59.4	64.6	63.2	< 0.01	0.96	0.43
NEFA, mEq/L	416[a]	331[ab]	274[b]	368[ab]	0.23	0.91	0.04
BHB, mg/dL	9.66	10.2	8.30	8.01	0.01	0.83	0.54
d 42 ± 3 after calving							
Glucose, mg/dL	59.0	65.0	62.6	67.9	0.06	< 0.01	0.75
NEFA, mEq/L	360[a]	207[b]	250[ab]	345[a]	0.73	0.47	< 0.01
BHB, mg/dL	8.43[ab]	8.57[ab]	10.1[a]	7.55[b]	0.59	0.05	0.03

[ab] Superscripts differ if treatment means in a row differ significantly ($P < 0.05$)

Another interesting observation made in the recent U of A study is the effect of SCFP on periparturient DMI. Cows fed SCFP had greater DMI on d 1 and 5 after calving (Figure 1). In this study, reductions in DMI during a 7-d period immediately before calving were minimal regardless of treatment, possibly because all cows were fed a controlled-energy close-up diet containing straw at approximately 30% of diet DM. However, cows fed SCFP had greater DMI on d 1 when cows were switched to lactation diets regardless of dietary starch content. In addition, on d 5 after calving, when cows on the control diets slightly decreased DMI, cows fed SCFP continued to increase DMI.

In addition, serum concentration of haptoglobin, an acute phase protein, was lower for cows fed SCFP supplementation on d 7 after calving (Figure 2), which might indicate that the cows had less subclinical disease, tissue damage, or infections. Supplementation of SCFP might have contributed to a more stable rumen fermentation environment (Li et al., 2013) or altered some inflammatory mediators (Zaworski et al., 2014; Li et al., 2016), leading to greater DMI during the periparturient period.

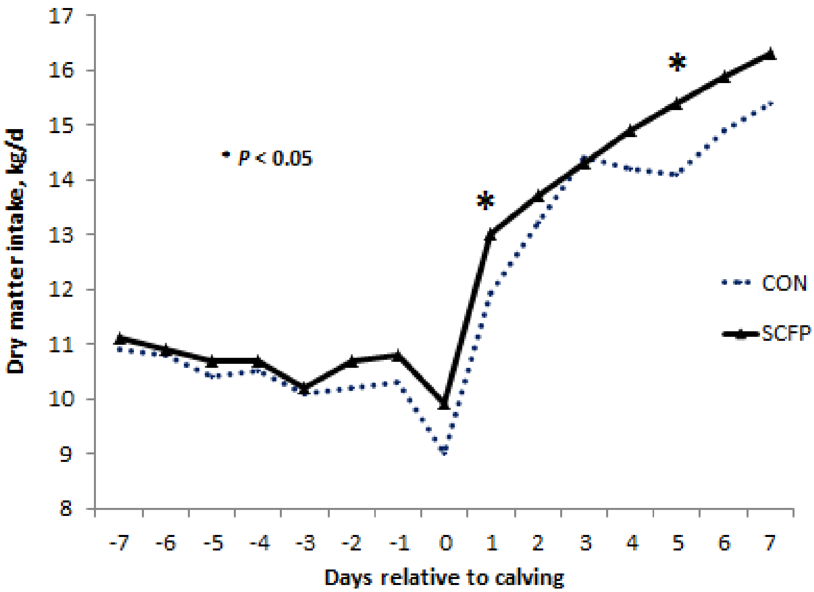

Figure 1. Effects of supplementation of a novel *Saccharomyces cerevisiae* fermentation product (SCFP) during the periparturient period on DMI (kg/d) from 7 d before calving to 7 d after calving

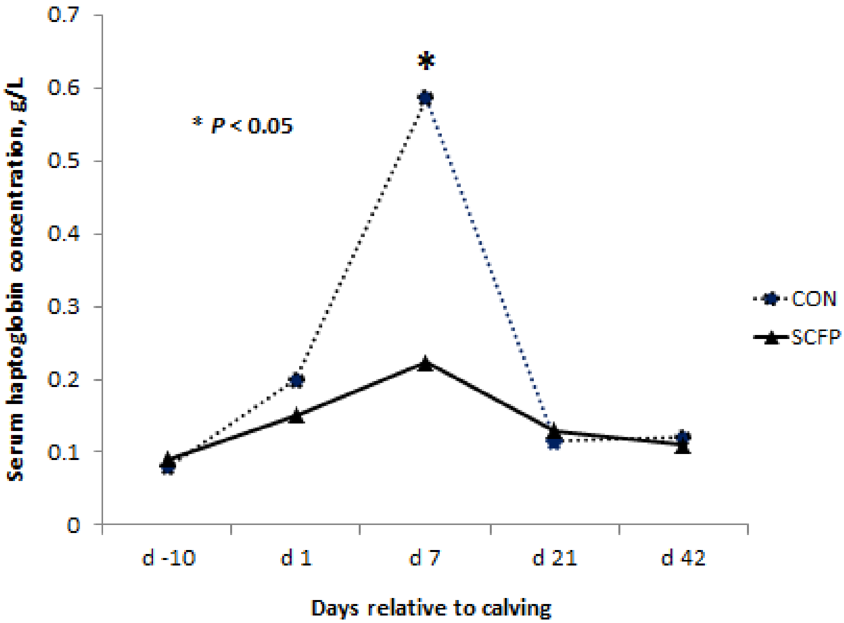

Figure 2. Effects of supplementation of a novel *Saccharomyces cerevisiae* fermentation product (SCFP) during the periparturient period on serum haptoglobin concentration (g/L) from 10 d before calving to 42 d after calving

▪ Conclusion

Increasing dietary fat and starch contents is a common approach to maximize energy intake and milk production for cows in peak lactation. However, fresh cows are under a unique physiological state and their responses are often different from cows in peak lactation. For example, some fresh cows, especially in a lipolytic state, do not respond positively to fat supplementation. Similarly, feeding high starch diets during the fresh period may decrease milk production, particularly if a low-starch controlled-energy diet is fed during the close-up period. As such, it is recommended to feed a different diet just for fresh cows to address their specific needs. This approach would also allow us to include some expensive supplements in their diets in a cost-effective manner because a small number of animals, who would show greater responses than the others, can be targeted. If it is difficult to prepare a different TMR for fresh cows, thus offering top-dressed long hay along with a common lactating cow TMR should be considered to allow fresh cows to consume more physically-effective fibre to mitigate the risk of SARA.

Optimizing nutritional management of fresh cows helps enable a smooth take off for successful lactation performance.

References

Beam, S. W., and W. R. Butler. 1998. Energy balance, metabolic hormones, and early postpartum follicular development in dairy cows fed prilled lipids. J. Dairy Sci. 81:121-131.

Carder, E. G., and W. P. Weiss. 2017. Short- and longer-term effects of feeding increased metabolizable protein with or without an altered amino acid profile to dairy cows immediately postpartum. J. Dairy Sci. 100:4528-4538.

Dann, H. 2016. Feeding the fresh cow: what is the ideal carbohydrate mix? WCDS Adv. Dairy Technol. 28:71-80.

de Souza, J, and A. L. Lock. 2017. Effects of timing of C16:0 supplementation on production and metabolic responses of early lactation dairy cows J. Dairy Sci. 100 (Suppl. 2):222.

Dieho, K., A. Bannink, A. L. Geurts, J. T. Schonewille, G. Gort, and J. Dijkstra. 2016. Morphological adaptation of rumen papillae during the dry period and early lactation as affected by rate of increase of concentrate allowance. J. Dairy Sci. 99:2339-2352.

Dyck, B. L., M. G. Colazo, D. J. Ambrose, M. K. Dyck, and L. Doepel. 2011. Starch source and content in postpartum dairy cow diets: Effects on plasma metabolites and reproductive processes. J. Dairy Sci. 94:4636-4646.

Keunen, J. E., J. C. Plaizier, L. Kyriazakis, T. F. Duffield, T. M. Widowski, M. I. Lindinger, and B. W. McBride. 2002. Effects of a subacute ruminal acidosis model on the diet selection of dairy cows. J. Dairy Sci. 85:3304-3313.

Keunen, J. E., J. C. Plaizier, L. Kyriazakis, T. F. Duffield, T. M. Widowski, M. I. Lindinger, and B. W. McBride. 2003. Short communication: Effects of subacute ruminal acidosis on free-choice intake of sodium bicarbonate in lactating dairy cows. J. Dairy Sci. 86:954-957.

Li, S., E. Khafipour, I. Yoon, M. Scott, J. C. Plaizier. 2013. Saccharomyces cerevisiae fermentation product stabilized rumen microbial communities of lactating dairy cows during subacute ruminal acidosis. Congress on Gastrointestinal Function, Abstr. #56296.

Li, S., I. Yoon, M. Scott, E. Khafipour, and J. C. Plaizier. 2016. Impact of Saccharomyces cerevisiae fermentation product and subacute ruminal acidosis on production, inflammation, and fermentation in the rumen and hindgut of dairy cows. Anim. Feed Sci. Technol. 211:50-60.

Mann, S., F. A. Leal Yepes, T. R. Overton, J. J. Wakshlag, A. L. Lock, C. M. Ryan, and D. V. Nydam. 2015. Dry period plane of energy: Effects of feed intake, energy balance, milk production, and composition in transition dairy cows. J. Dairy Sci. 98:3366-3382.

Maulfair, D. D., K. K. McIntyre, and A. J. Heinrichs. 2013. Subacute ruminal acidosis and total mixed ration preference in lactating dairy cows. J. Dairy Sci. 96:6610–6620.

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, Pelton, S. H., 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.

Palmquist, D. L. 1994. The role of dietary fats in efficiency of ruminants. J. Nutr. 124:1377S-1382S.

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.

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 post-partum phase of the transition period. J. Dairy Sci. 92:3341-3353.

Piantoni, P., A. L. Lock, and M. S. Allen. 2015. Saturated fat supplementation interacts with dietary forage neutral detergent fiber content during the immediate postpartum and carryover periods in Holstein cows: Production responses and digestibility of nutrients. J. Dairy Sci. 98:3309-3322.

Sklan, D., U. Moallem, and Y. Folman. 1991. Effect of feeding calcium soaps of fatty acids on production and reproductive responses in high producing lactating cows. J. Dairy Sci. 74:510-517.

Subramaniam, E., M. G. Colazo, M. Gobikrushanth, Y. Sun, A. Ruiz-Sanchez, P. Ponce-Barajas, M. Oba, D. J. Ambrose. 2016. Effects of reducing dietary starch content by replacing barley grain with wheat dried distillers grains plus solubles in dairy cow rations on ovarian function. J. Dairy Sci. 99:2762-2774.

Sun, Y., and M. Oba. 2014. Effects of feeding a high-fiber byproduct feedstuff as a substitute for barley grain on rumen fermentation and productivity of dairy cows in early lactation. J. Dairy Sci. 97:1594-1602.

Zaworski, E. M., C. M. Shriver-Munsch, N. A. Fadden, W. K. Sanchez, I. Yoon, and G. Bobe. 2014. Effects of feeding various dosages of Saccharomyces cerevisiae fermentation product in transition dairy cows. J. Dairy Sci. 97:3081–3098