Feeding to Minimize Aciodosis and Laminitis in Dairy Cows

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Introduction

Sub-acute rumen acidosis (**SARA**) is a prevalent problem for dairy herds (Cook et al., 2004; Nordlund et al., 2004) as characterized by having more than 25% of cows sampled via rumenocentesis 4 to 8 hours after a total mixed ration (**TMR**) meal with ruminal pH less than 5.5 (Nordlund et al., 2004). Ruminal pH is largely a function of the balance between the production of volatile fatty acids (**VFA**) from the fermentation of carbohydrates, their neutralization by salivary and dietary buffers, and their removal by absorption across the rumen wall or passage from the rumen (Allen, 1997), and SARA is caused by the consumption of high amounts of ruminally-available carbohydrate, low amounts of effective fiber, or both (Nocek, 1997). Laminitis, an aseptic inflammation of the dermal layers inside the hoof and a major source of lameness for dairy herds, has been linked to SARA (Nocek, 1997; Cook et al., 2004; Nordlund et al., 2004; Stone, 2004).

Despite diet formulation guidelines for neutral detergent fiber (**NDF**) from forage, total NDF and non-fiber carbohydrate (**NFC**; Dairy NRC, 2001; Stone, 2004), physically-effective NDF (peNDF; Mertens, 1997; Stone, 2004), and starch (Nocek, 1997) along with the feeding of TMR, some degree of SARA may be inevitable in high-producing dairy herds because total chewing and rumination times, and as a consequence salivary buffer flow, decline per unit of rumen-fermentable organic matter (**RFOM**) intake or VFA production as RFOM intake increases (Shaver, 2002). An increased intake of RFOM as milk production increases is a normal consequence of high milk production, because of increases in DM intake and the feeding of higher-concentrate diets to increase dietary energy density (Dairy NRC, 2001). Further, bunk management and cow comfort have been implicated as risk factors for SARA and laminitis in dairy herds (Shaver, 2002; Cook et al., 2004; Stone, 2004). The foregoing discussion highlights the challenges that we face in our efforts to minimize SARA and laminitis in today's dairy herds, and underscores that the margin for error in our feeding programs is small.

Readers are referred to several thorough reviews on SARA/laminitis (Nocek, 1997; Shaver, 2000; Shaver, 2002; Cook et al., 2004; Nordlund et al., 2004; Stone, 2004), as the emphasis of this paper will be to supplement their contents with regard to current hot-topic areas.

Transition Diets

Lead feeding, the practice of increasing the proportion of concentrate in the TMR during the last few weeks prior to calving, has become common practice. Intake of either excessive or minimal amounts of concentrate during the close-up dry period may increase the risk of SARA. Excessive lead feeding is probably not a common risk factor for SARA, because low dry matter intake (**DMI**) during the transition period (Bertics et al., 1992) would reduce the rate and extent of post TMR-meal decline in ruminal pH and herd managers tend to be relatively conservative with concentrate amounts for dry cows. Minimal lead feeding may increase the risk of SARA through failure to increase the VFA absorptive capacity of the ruminal papillae (Dirksen et al., 1985) and adapt the ruminal microbial population to starch during the close-up dry period prior to the feeding of high-energy (starch) milking cow diets. Further, fresh-cow transition diets and the relative composition of close-up dry-cow versus fresh-cow transition diets may influence the risk of SARA. Cook et al. (2004) suggested that transition cows may be at an increased risk of developing laminitis following a SARA trigger.

Donovan et al. (2004) evaluated the influence of close-up dry-cow and fresh-cow transition diets on the incidence of laminitis and SARA. Refer to Table 1 for a partial presentation of their data. Cows were fed either low or high energy diets during the close-up dry period prior to calving for 24 days on average, then post-calving were fed a common energy diet for five days on average followed by either low or high diets for 16 days on average followed by the common energy diet again from 21 to 70 days in milk (**DIM**). Treatments were as follows: Pre High NE_L, Post Low NE_L; Pre High NE_L, Post High NE_L; Pre Low NE_L, Post Low NE_L; Pre Low NE_L, Post High NE_L. Average rumenocentesis pH measurements (Garrett et al., 1999) were not affected by treatment ($P > 0.05$). Lowest ruminal pH for samples taken at 8, 22, and 70 DIM was 0.2 units lower ($P < 0.05$) for cows fed Post High NE_L (ruminal pH of 5.61 on average) than Post Low NE_L (ruminal pH of 5.81 on average) diets. The percentage of cows with ruminal pH less than 5.8 at 8 and 22 DIM was greater ($P < 0.05$) for cows fed Post High NE_L (62% on average) than Post Low NE_L (34% on average) diets. Using a more conservative cut-off for SARA (Nordlund et al., 2004), the percentage of cows below ruminal pH of 5.5 were 41% and 24% for Post High NE_L and Post Low NE_L, respectively. Hoof scores at 60 DIM were worst ($P < 0.05$) for cows fed the Pre Low NE_L, Post High NE_L treatment. These results lend support to practice of feeding fresh-cow transition diets that stair-step energy content gradually to the high-cow diet, especially when low- to moderate- energy close-up dry-cow diets are fed.

Heat Stress

Mishra et al. (1970) reported lower ruminal pH for dairy cows in hot-humid (85° C and 85% relative humidity) than cool (65° C and 50% relative humidity) environments when fed either high-roughage (35% grain; pH of 6.1 vs. 6.4) or high-grain (65% grain; pH of 5.6 vs. 6.1) diets, possibly because of decreased rumination activity (Collier et al., 1982) and increased slug feeding (Mallonee et al., 1985) during heat stress. Leonardi and Armentano (2003) reported extensive sorting away from long TMR particles, and this feeding behavior may increase during heat stress as cows attempt to reduce metabolic heat production by selecting away from forage toward concentrate (McDowell, 1972). Stone (2004) recommended that dietary peNDF content be increased and NFC content decreased during heat stress to reduce the risk of SARA. Heat stress limits the amount of time cows spend in stalls which may increase risk of laminitis (Cook et al., 2004) since laminitis increased in cows that spent more time standing on concrete rather than lying in stalls (Colam-Ainsworth et al., 1989). Managing facilities to optimize cow comfort and minimize heat stress is an important component of laminitis prevention.

Feed Additives

There are several feed additives available for use in dairy cattle diets that may minimize SARA and (or) laminitis.

Rumensin® (monensin sodium) supplementation of dairy cattle diets for increased milk production efficiency was approved recently (FDA-CVM, 2004). Subclinical ketosis was reduced in transition cows treated with a monensin controlled-release capsule (Green et al., 1999). Monensin has been used to prevent lactic acidosis in cattle (Nagaraja et al., 1981) and monensin reduced lactic acid concentrations in vitro through inhibition of the lactic acid producer Streptococcos bovis (Nagaraja et al., 1987), which suggests that monensin may have a role in attenuation of SARA and laminitis. In dairy cows, monensin increased ruminal pH in one study (Green et al., 1999) but did not influence ruminal pH in others (Mutsvangwa et al., 2002; Osborne et al., 2994; Ruiz et al., 2001). Monensin supplementation of feedlot cattle diets increased meal frequency and reduced average meal size in two trials reviewed by Milton

(2000). The efficacy of monensin for minimizing SARA and laminitis in dairy cattle remains to be determined.

Ruminal pH declines following meals with the rate of pH decline increasing as meal size increases and as dietary NDF content decreases (Allen, 1997). Dietary supplementation of sodium bicarbonate attenuates the decline in ruminal pH that is observed post feeding (Erdman, 1988), and may attenuate SARA. The recommended inclusion rate for sodium bicarbonate is 0.75 to 1.0% of TMR dry matter. Keunen et al. (2003) reported that cows with experimentally-induced SARA did not attenuate SARA by consuming free-choice sodium bicarbonate.

Researchers reported that 20 mg/cow/day supplemental dietary biotin reduced the laminitis-related hoof lesions, white-line separation (Hedges et al., 2001; Fitzgerald et al., 2000; Midla et al., 1998; Potzsch et al., 2003) and sole ulcers (Bergsten et al., 2003), and improved sole ulcer healing (Lischer et al., 2002). Dietary biotin supplementation did not influence ruminal VFA (Zimmerly and Weiss, 2001) or apparent total tract organic matter digestibility (Majee et al., 2003), and it is unlikely that reductions in laminitis-related hoof lesions occur via an attenuation of SARA but rather via biotin's role in keratization of hoof epidermis (Tomlinson et al., 2004).

Nocek et al. (2000) reported reduced laminitis-related hoof lesions in five commercial dairy herds during the year of dietary supplementation with complexed trace minerals (zinc, manganese, copper and cobalt) relative to the year prior when these herds were not supplemented with this complexed trace mineral mixture. The role of trace minerals in keratization of hoof epidermis (Tomlinson et al., 2004) could explain this response.

Novel use of direct-fed microbials (**DFM**) to enhance lactate utilization within the rumen has been reported with specific yeast strains (Dawson, 1995), yeast culture stimulation of *Selenomonas ruminantium* (Martin and Nisbet, 1992), DFM mixture containing *Lactobacillus plantarum*, *Enterococcus faecium*, and yeast (Nocek et al., 2002), *Megasphaera elsdenii* (Kung and Hession, 1995), and *Propionibacterium* strains (Parrott et al., 2001; Krehbiel et al., 2003). Controlled research trials demonstrating efficacy for attenuating SARA/laminitis in dairy cows are lacking.

Ration Preparation and Delivery

Extensive variation in DM, NE_L and NDF concentrations found within bunker silos is presented in Table 2 (Stone, 2004). This emphasizes the importance of meticulous face management with careful use of loader buckets or face shavers to minimize batch to batch variation and for obtaining samples representative of what is being fed. Switching between silo bags abruptly can cause wide swings in nutrient delivery. Errors in nutrient delivery can occur because of failure to routinely determine the DM content of wet forages for adjustment of rations to maintain correct and consistent DM proportions of forage to concentrate. This becomes especially important after periods of heavy rainfall. To ensure consistent and accurate nutrient delivery and minimize SARA, effort should be made to assess and control these sources of error.

Mertens (1997) provided a minimum dietary peNDF guideline of 22% (DM basis). Particle size influences peNDF (Mertens, 1997). Mixing the TMR for too long a period of time reduces particle size of the batch mix, and was common in high-incidence laminitis herds (Possin et al., 1995). Leonardi and Armentano (2003) reported extensive sorting away from long TMR particles, which can reduce the peNDF content of the diet consumed relative to the TMR mixed depending on the proportion of long TMR particles, degree of sorting away from long particles, and the weigh-back proportion. Procedures are available to evaluate forage, TMR, and weigh-back particle size distributions in commercial testing laboratories (ANSI, 1988) or on the dairy (Lammers et al., 1996; Kononoff et al., 2003) to obtain a more accurate assessment of peNDF content of the diet consumed.

Grain type (corn vs. barley), harvest/storage method (dry vs. high-moisture; DM content), and processing (rolled vs. ground vs. steam-flaked; fineness of grind) and corn silage DM content and processing influence ruminal starch degradability (Nocek and Tamminga, 1991) which is a risk factor for SARA/laminitis (Nocek, 1997). The guideline provided by Nocek (1997) for ruminal starch degradability was 60% to 70% of total dietary starch. However, analytical procedures for determining ruminal starch degradability of grains, corn or small-grain silages, or TMR have generally been unavailable in commercial feed testing laboratories. Blasel et al. (2005) reported on a laboratory method which provides an index of degree of starch availability (**DSA**) and ranked samples of corn grain appropriately for differences in particle size, DM content, and vitreousness. Data from corn silage and TMR samples are limited. Research and field experience with DSA as a nutritional diagnostic tool is needed to determine its usefulness for minimizing SARA and laminitis.

SARA/Cow Comfort Interaction and Laminitis

SARA may or may not result in an increased incidence of laminitis. Environmental factors that influence lying and standing behavior may worsen laminitis-related hoof lesions triggered by SARA (Cook et al., 2004). Nordlund (2000) reported on the diagnosis of SARA without a high corresponding incidence of laminitis in three grazing herds, and attributed this to the fact that the cows were on dirt rather than concrete. Colam-Ainsworth et al. (1989) reported increased laminitis in cows that spent more time standing on concrete rather than lying in stalls. Comparing his findings in grazing herds to diagnostic work-ups done in confined herds, Nordlund (2000) suggested that the degree of SARA needed to trigger laminitis is greater for cows on dirt than for cows with significant exposure to concrete. Cow comfort and her environment must be evaluated when attempting to minimize laminitis in dairy herds.

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Table 1. Transition diets and laminitis/SARA (Donovan et al., 2004) [1].

	Pre High NE_L Post Low NE_L	Pre High NE_L Post High NE_L	Pre Low NE_L Post Low NE_L	Pre Low NE_L Post High NE_L
Diet Concentrate (% DMB)				
Prepartum, 24 days	50	50	45	45
Postpartum, 5 days	60	60	60	60
Postpartum, 16 days	60	65	60	65
Postpartum, 21-70 DIM	60	60	60	60
Diet NDF (% DMB)				
Prepartum, 24 days	40	40	45	45
Postpartum, 5 days	34	34	34	34
Postpartum, 16 days	36	30	36	30
Postpartum, 21-70 DIM	34	34	34	34
Diet NE_L (Mcal per lb. DM)				
Prepartum, 24 days	0.74	0.74	0.69	0.69
Postpartum, 5 days	0.79	0.79	0.79	0.79
Postpartum, 16 days	0.77	0.81	0.77	0.81
Postpartum, 21-70 DIM	0.79	0.79	0.79	0.79
Rumenocentesis pH				
-14 DIM	6.25	6.04	6.18	6.23
8 DIM	6.00	5.82	6.07	5.93
22 DIM	5.92	5.79	5.84	5.73
Lowest Postpartum pH [2]	5.84[a]	5.59[b]	5.78[a]	5.64[b]
% pH < 5.8 [3]	35[b]	58[a]	32[b]	65[a]
Hoof Score[4]	2.0[a, b]	1.4[b]	1.0[b]	2.6[a]

[a, b]Means in the same row with different superscripts differ ($P < 0.05$).
[1]Ninety-eight cows completed the study.
[2]Lowest ruminal pH for samples taken at 8, 22, and 70 DIM.
[3]Percentage of samples taken at 8 and 22 DIM with pH less than 5.8.
[4]Means of sum of hoof scores (0 = no hemorrhages or discoloration; 1 = slight discoloration or yellow staining; 2 = moderate hemorrhages; 3 = severe hemorrhages or secondary horn disintegration; 4 = exposed corium/sole ulcer) at zones 3 (abaxial wall-bulb junction) and 4 (sole-bulb junction) of sole at 60 DIM.

Table 2. Percentage deviations from minimum analytical result for lower, middle, and upper face samples within nine haylage and eleven corn silage bunkers on nine commercial dairies in New York (Stone, 2004).

% Deviation	DM	NE_L	NDF
Haylage			
Average	21.0	9.9	14.7
Minimum	5.2	1.6	5.4
Maximum	44.7	20.0	24.8
Corn Silage			
Average	12.3	3.1	8.6
Minimum	1.3	1.4	0.5
Maximum	55.0	5.6	18.6