MANAGEMENT STRATEGIES AGAINST RUMINAL ACIDOSIS

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INTRODUCTION

With increasing production have come increases in subclinical ruminal acidosis in dairy cattle herds. As we strive to meet the animal's energy requirements by increasing energy levels in rations, higher levels of grain, and lower levels of forage have become the norm. Rather than enhancing performance, these rations can lead to problems attendant with ruminal acidosis: reduced milk production, digestive upset, laminitis, and associated ills that can lead to involuntary culling. With some of these health problems, there is no real cure. Ruminal acidosis is something to be prevented, not repaired.

Subclinical, or chronic, ruminal acidosis is best described as a syndrome related to a fermentative disorder of the rumen. Although it involves a lowering of ruminal pH below pH 5.5 to 5.6 (Nocek, 1997; Owens, et al., 1998), it is not adequate to define ruminal acidosis as being caused by low ruminal pH. The ruminal problems can typically be traced to misfeeding of the ration or of highly digestible carbohydrates, underfeeding of effective fiber, or all of the above. Symptoms associated with subclinical ruminal acidosis include:

- Reduction in ruminal pH
- Rumen hypermotility or stasis
- Reduced rumination (cud chewing)
- Great daily variation in feed intake
- Feces in the same feeding group varies from firm to diarrhea
- Feces foamy, contains gas bubbles
- Appearance of mucin/fibrin casts in feces
- Increase in fiber particle size (> 0.5 inch) in feces
- Appearance of undigested fiber in feces
- Appearance of undigested, ground (≤ 1/4 inch) grain in feces
- Reduced feed efficiency
- Reduced production compared to what the ration should support.

The chain of ruminal events that is associated with these symptoms is shown in Figure 1. What do the symptoms listed above represent?

Increased Particle Size/Undigested Material in Feces

Large fiber particles or noticeable ground grain in the feces suggest that feed is not being retained in the rumen for a sufficient period to be fermented by the microbes, or to be reduced in size through rumination or microbial digestion. The depression in ruminal digestion may be

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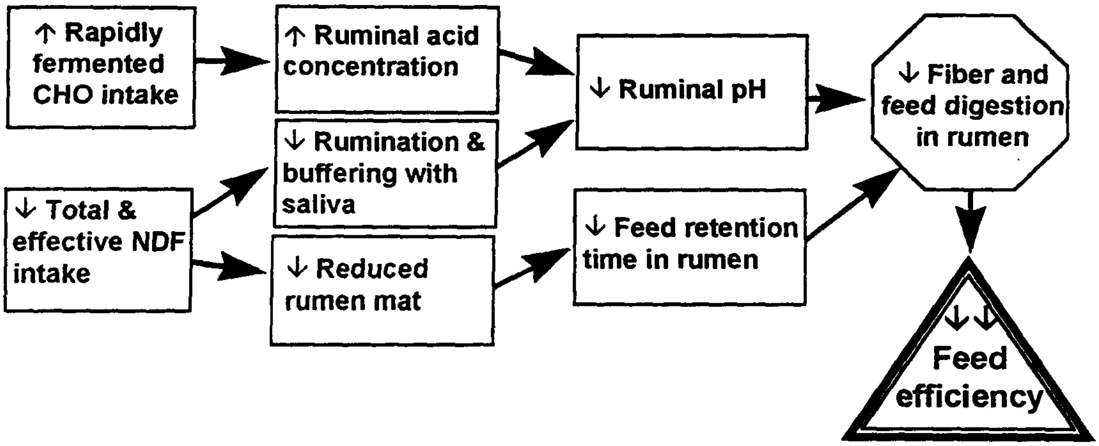

Figure 1. Chain of events in ruminal acidosis.

related to low pH (Strobel and Russell, 1986). An inadequate fiber mat may not effectively retain larger particles in the rumen. Both of these situations can be related to inadequate effective fiber (eNDF) intake. The eNDF is fiber in the ration that enhances rumination and rumen motility. Generally, when there is adequate eNDF in the ration, fecal particle size is smaller and ground grain is less apparent, than when fiber requirements are not met.

Undigested feed in feces is indicative of an overall reduction in digestibility of the feed. Both fiber and starch can escape digestion. Long pieces of fiber from forage, or even cottonseed with the lint still intact will pass undigested through the gastrointestinal tract if they are not retained in the rumen for digestion. The particles of ground grain in feces may contain 6 to 18% starch (M.B. Hall, unpublished). Reduced digestion of feed represents a loss of ration nutrients. Consequently, the predicted protein and energy supplies for the ration overestimate what the cow actually receives.

Mucin/Fibrin Casts or Gas Bubbles in Feces

When feed is fermented in the rumen, the organic acids are absorbed across the rumen wall, the gas (carbon dioxide and methane) is eructated (belched) out by the cow, and the microbial protein passes to the small intestine for digestion and absorption. When fermentable substrates pass to the hindgut (cecum and large intestine) they are fermented there by bacteria. The microbial protein produced is not absorbed, but passes out with the manure. Gas produced from hindgut fermentation can appear as bubbles in the manure. The organic acids can be absorbed by the gut. However, a major difference between the hindgut and the rumen is the potential for the fermentation to be buffered. Where rumination and mixing with saliva provide buffers to reduce the extent of pH decline in the rumen, no system of that magnitude exists for the hindgut. When a great deal of fermentable carbohydrate reaches the hindgut, its fermentation to organic acids can result in injury to the gut. The increased acidity and action of the organic acids on the cells of the large intestine can result in a sloughing of the surface cells, or epithelium. When the damage is sufficiently severe, the intestine secretes mucous or fibrin to protect the injury (Argenzio, et al., 1988; Argenzio and Meuten, 1991). Depending upon the severity of the damage, the gut can repair itself in a few hours to a day (R. A. Argenzio, personal communication). The mucin/fibrin casts found in the feces often have the tubular form of the gut;

they are evidence that intestinal damage has occurred. Damage to the large intestine may play a role in causing the diarrhea often seen with ruminal acidosis.

Reduced Feed Efficiency

If the site of digestion is being shifted from the rumen to the hindgut, or feed digestion is reduced, it is no wonder that feed efficiency suffers during ruminal acidosis. The amounts of nutrients available to the cow are diminished. The argument has been raised that increased grain and decreased forage are necessary to meet the energy requirements of the cow. However, if concentrate levels are increased to the point that fiber needs are not met, the analyzed or tabular TDN or net energy levels used to formulate the ration are meaningless. In the pursuit of providing the cow with more energy, violation of the rules for formulating a balanced ration actually reduces the amount of energy that the ration provides. This quote by Dr. Paul W. Moe, a USDA researcher who did much work in the area of net energy, best explains the situation (Moe, 1976):

> "…The net energy value of a single feedstuff, however, is not a constant but is influenced by such factors as the composition of the remaining portion of the diet, the level of the feed intake, the physiological state of the animal that consumes the feed, etc. This means that while a net energy value may represent the best estimate of the real energy value of a feed in a given situation, it should not be considered as a constant. ….The net energy value listed in a table usually represents an optimum value, that is the value of that feed when incorporated into a "normal" or "balanced" diet. The value may be considerably less than that if fed in excessive amount or in a diet which has a nutrient deficiency."

In this light, including excessive amounts of concentrates in an effort to increase ration energy levels is self-defeating.

Preventing Ruminal Acidosis

Prevention of subclinical ruminal acidosis requires both nutritional and management approaches.

Fiber

Feeding the adequate proportion and type of fiber is important, however, "adequacy" can be difficult to formulate. Perhaps to an even greater extent than for other nutrients, adequacy of dietary fiber is determined by the interaction of the cow and the ration. The NRC (1989) general recommendations for lactating cow diets are for 28% of ration dry matter as NDF, and that 75% of the NDF be supplied from forage. Mertens (1985) has suggested that NDF intakes of 1.2 ± 0.1 percent of live weight with 70 to 80% of the NDF supplied from forage is optimum. These guidelines are subject to change depending upon fiber form and source. The specification that a percentage of the NDF be supplied by forage is an effort to assure that there is adequate eNDF in the ration. The difficulty is that there is no common agreement on a set system to assess the effectiveness of NDF, in part, because so many factors can affect "effectiveness". Fiber's effectiveness relates to its particle size, digestibility, density, and hydration among other factors.

Effectiveness of a fiber source can even vary depending upon the characteristics of the other feeds in the ration (Mooney and Allen, 1997). Particle separation systems are available to objectively evaluate particle size in rations as a way of estimating the amount of effective fiber (Lammers, et al., 1996).

The usefulness of any eNDF system depends upon how well it describes the fiber that is actually consumed. If cows can select the feeds they consume, any estimation of eNDF intake will be poor. Evaluating eNDF intake on different feeding systems requires different approaches.

- Total Mixed Rations - The feed fed, and the feed remaining should be examined to determine the extent to which sorting took place. If the ration is not being sorted, the feed remaining should look similar to that which was fed. Observation of the cows as they eat also makes clear whether they can sort, and which feeds they select for or against. This may vary by animal (Coppock, et al., 1974).

- Feeding to an Empty Bunk - Since no feed remains to be evaluated, the only way to discern whether sorting is taking place is to observe the cows as they eat. Particularly if bunk space is limited, the first cows may sort the ration for preferred feeds, with the remainder providing an entirely different ration to the cows that access the bunk later.

- Offering Individual Feeds - When forages and concentrates are offered separately, particularly to groups of cows, there is no accurate way to assess what ration individual cows consumed. The ration consumed by the herd may represent an average of very high and low concentrate diets eaten by individual animals.

Cows are quite adept at sorting out longer pieces of forage. Sorting of total mixed rations can be minimized by chopping the forage to 1 to 2 inch lengths and raising the moisture level of the ration so that feeds do not sift apart.

The cow is the final arbiter of whether her fiber requirement is met. A good general rule is that the ration contains adequate amounts of effective fiber if 50% of the cows not eating or sleeping are chewing their cuds. Manipulation of the ration and feeding management need to be explored to achieve this goal.

Neutral Detergent-Soluble Carbohydrates (NDSC)

Controlling the level and type of NDSC in the ration is essential to preventing ruminal acidosis. The NDSC (a.k.a., NSC or NFC) include organic acids, sugars, starch and soluble fiber such as pectic substances. Restricting NSC to 35 to 40% of ration dry matter when the NDSC is largely sugar or starch, or 40 to 45% when other carbohydrates predominate has been suggested (Hoover and Miller, 1995). It does appear that different NDSC carbohydrates differ in their effects on ruminal pH. Sugars and starch may ferment to lactic acid, which is a 10-fold stronger acid than acetic, propionic, or butyric. Soluble fiber, such as pectic substances, ferment rapidly, but their fermentation is depressed at lower pH (Ben-Ghedalia, et al., 1989; Strobel and Russell, 1986), so their acid contribution may be reduced at lower ruminal pHs. Because different types of NDSC differ in their effects on ruminal pH, it is reasonable to formulate rations considering NDSC type, rather than total.

The effects of the quantities of NDSC fed varies with their rates of fermentation. Rapidly fermenting carbohydrates, such as sugars, soluble fiber, and some starches, have the potential to decrease ruminal pH rapidly by virtue of the sheer mass of organic acids presented to the rumen in a relatively short period of time. In feedlot cattle, a greater risk of ruminal acidosis is reported when more rapidly fermented carbohydrate sources such as wheat (Elam, 1976), steam-flaked sorghum (Reinhart, et al., 1997) are fed. Increased gelatinization, physical availability, and digestibility of grains accomplished through heat and pressure processing, reduction in particle size, or high moisture ensiling can increase the rate of starch digestion.

The effects of different NDSC on ruminal pH was explored in a recent study with lactating dairy cows (E. Leiva and M. B. Hall, unpublished). Three ruminally cannulated cows in a reversal trial were fed one of two corn silage/alfalfa hay-based diets containing approximately 40% calculated NDSC, 36% NDF, and 17.8% CP. The diets differed in that their NDSC came largely from hominy (starch) or from dried citrus pulp (sugars and soluble fiber). The citrus and hominy diets contained 4.7 and 2.5% soluble sugars, 15.0 and 26.4% starch, and 13.8 and 8.2% soluble fiber as a percentage of ration dry matter, respectively. The mean pH values of rumen samples taken over 10 hours did not differ for the two diets (citrus: 6.18, hominy: 6.24; $P = 0.12$)) However, the shapes of the pH curves differed due to a significant diet by hour interaction ($P = 0.04$) (Figure 2). The pH on the citrus diet declined more rapidly, and reached its lowest point more quickly than did the hominy diet. However, at 10 hours after feeding the pH of the hominy diet had not reached its lowest point. Further trials to compare the ruminal effects of different NDSC may provide the information needed to allow more refined manipulation of ruminal pH through ration formulation.

To minimize the risk of ruminal acidosis and optimize/maximize the provision of rapidly fermented carbohydrate in the ration of dairy cows a balance of NDSC types is recommended. Tentative suggestions for target levels of NDSC to be included in rations are: 5% sugars, 10% soluble fiber, and 20% starch, all as a percentage of dry matter. These recommendations presume that effective fiber requirements are met. Tabular values for some of the NDSC fractions in feeds are in Table 1.

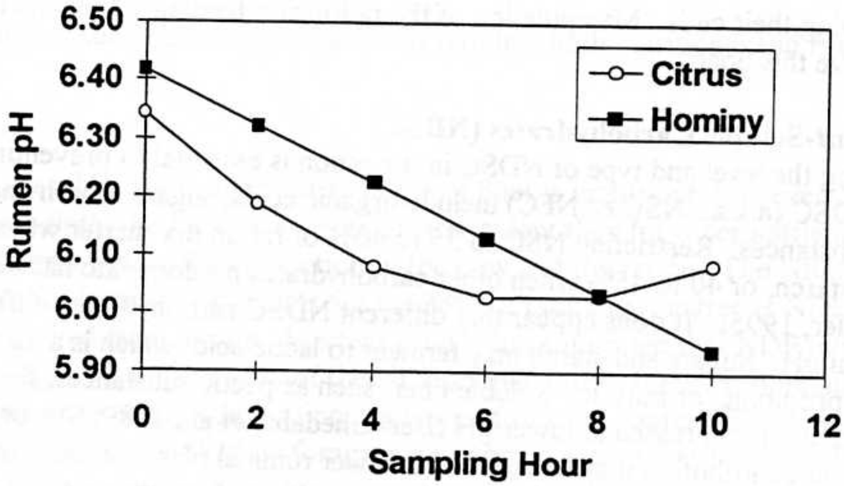

Figure 2. Regression curves of ruminal pH results for citrus and hominy rations. Hour 0 sample was taken immediately before feeding.

Table 1. Neutral detergent-soluble carbohydrate composition of feeds (% of dry matter).*

Feed	Organic Acids	Sugars	Starch	Soluble Fiber
Alfalfa hay	6	8	3	14
Alfalfa silage	10 - 14	1 - 2	0.7 – 1	12 - 13
Almond hulls	8	33	1	17
Citrus pulp	9	29	1	30
Corn grain	Less than 1	Less than 1	64 - 70	8
Corn silage	8 - 10	Less than 1	19 - 30	4 - 6
Whole cottonseed	----	----	1	11
Cottonseed hulls	----	----	Less than 1	4
Soybean meal (48%)	4	11	1	14
Soybean hulls	Less than 1	Less than 1	1	20
Sugar beet pulp	Less than 1	12	Less than 1	28 - 30
Timothy hay	5	9	Less than 1	6
Ground wheat	Less than 1	2	65	9
Wheat middlings	5	5	21	3

* Note: These values represent few analyses. They do not give a complete picture of the variation within and among feeds.

Buffers

Dietary buffers do not eliminate the root causes of ruminal acidosis, but they can help in its management. Sodium bicarbonate and sodium sesquicarbonate are two common buffers used in dairy cattle rations. Both have been shown to improve milk fat percentage and/or milk yield. A review of forty-one studies of sodium bicarbonate use in dairy cattle rations averaging 57% concentrate showed varying responses depending upon the base forage fed (Staples and Lough, 1989). When corn silage was the main forage, cows produced an average of 1.8 lb more milk and 0.22% higher milk fat with sodium bicarbonate supplementation. With grass/legume silage or hay, results were inconsistent. Cows fed cottonseed hull-based diets showed little production response to sodium bicarbonate feeding. Feeding sodium bicarbonate at a rate of 0.75% of ration dry matter is recommended for cattle suffering from heat stress (West, 1994).

Dietary buffers have been purported to work by increasing ruminal pH. Another theory for their action is that when buffers are fed, cattle increase their water intake (Russell and Chow, 1993). This increases the ruminal dilution rate which in turn increases the flow of liquid and undegraded starch from the rumen.

Feeding Regimen

An additional risk factor for ruminal acidosis is "slug feeding" of high concentrate rations. This relates to the quantity of readily fermented NDSC present in the rumen at any point in time. Rapid consumption of rations containing adequate fiber is not as likely to cause ruminal problems because the fiber slows intake, decreases meal size, dilutes the NDSC, and increases rumination and saliva production (Owens, et al., 1998). Various situations which can result in cattle consuming large quantities of concentrate at one time include: Dose feeding of grain in bunk, parlor, or individual cow settings; inadequate bunk space/feed provision in which cows crowd the bunk and consume as much as they can as fast as they can; changes in intake patterns due to passing weather fronts; and irregularities in feed provision in which cows are left without feed for an extended period of time. Consider that withholding feed for 12 to 24 hours and then allowing animals access to 150% of the normal day's feed allotment is a common experimental method for inducing ruminal acidosis (Owens, et al., 1998). Feeding multiple times per day is recommended. Yearling dairy heifers fed high grain diets twice per day went for a longer period without going off feed than did heifers fed once per day (Tremere, et al., 1968). In general, reducing meal size while providing sufficient amounts of feed are positive steps towards reducing the incidence of ruminal acidosis.

Heat Stress

Changes in a cow's behavior and acid-base balance during heat stress predispose her to ruminal acidosis. Heat stress alters a cow's acid-base balance. As a cow pants and exhales carbon dioxide, it appears that the total amount of buffering capacity within her system is decreased (Dale and Brody, 1954). In addition, changes in feeding behavior such as consuming feed in fewer meals (slug feeding) and decreased rumination may lead to decreases in ruminal pH even on rations containing adequate fiber. In a University of Missouri study that tested the effect of ambient temperature on rumen environment (Mishra, et al., 1970), lactating Holstein cows were fed high roughage or high concentrate diets at ambient temperatures of 65°F (cool) or 85°F (hot) with relative humidities of 50% and 85%, respectively. Ruminal pH was lower at the higher temperature and on the higher concentrate ration ($p < 0.01$) (Figure 3). There was also an interaction of diet and temperature ($p < 0.01$). Ruminal ammonia and lactic acid concentrations also were significantly higher for the hot treatment ($p < 0.01$). Other studies have also reported

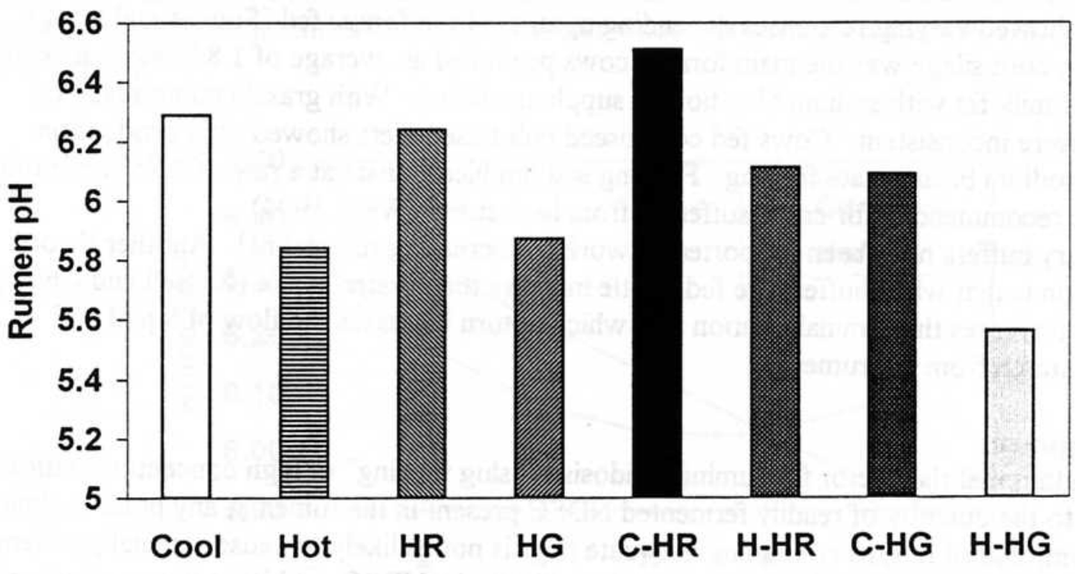

Figure 3. Ruminal pH changes with ambient temperature and diet (Mishra, et al., 1970). Cool (C) = 65°F ambient temperature, Hot (H) = 85°F ambient temperature, HR = high roughage diet, HG = high grain diet.

decreased ruminal pH in hotter vs. cooler ambient temperatures (Niles, et al., 1998; Bandaranayaka and Holmes, 1976). The changes in the rumen appear to be responses to ambient, not ruminal temperatures (Gengler, et al., 1970).

The most effective management for reducing the impact of heat stress on ruminal pH is to cool the cows. Fans, sprinklers, misters, cooling ponds, or shade can be used in cooling systems. A recent University of Florida study suggests that shade alone may be insufficient to decrease heat stress in lactating Holstein cows. Cows housed in a freestall barn were provided with shade, but no other cooling. The animals exhibited signs of heat stress including panting, elevated body temperatures, and increased respiration rates (A. Akinyode, J. P. Jennings, and M. B. Hall, unpublished).

The common practice of adding more concentrate to rations in summer is not well advised. The rationale for decreasing forage and increasing grain during heat stress is to meet animal energy demands in the face of decreasing dry matter intake. If, as in the Missouri study, feeding more concentrate further depresses ruminal pH, little may be gained, and more may be lost by compromising the cow's health. Fiber should be provided at levels to meet animal requirements under all conditions. If the ration is palatable and contains appropriate levels of fiber and NDSC, further altering the diet for heat stress may be counterproductive.

Financial Impact

The costs associated with subclinical ruminal acidosis are difficult to pinpoint. The disorder itself is insidious. Setting a confirmed cause and effect to allocate health disorders to chronic acidosis is the problem. But consider, what is the cost to the farm for each case of laminitis? For each case of digestive upset? For each cow that is culled as a cripple? For reduced production because cows eat less because they have sore feet or digestive upset? For reduced feed efficiency that depresses the nutrient value of feeds even though the price paid per ton remains the same? The potential costs to the dairy industry are huge. They are also unnecessary. Subclinical ruminal acidosis is a problem that is manageable if we choose to manage against it.

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