RUMEN ACIDOSIS: CARBOHYDRATE FEEDING CONSIDERATIONS

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INTRODUCTION

With increasing production has come an increase in the reports of ruminal acidosis in dairy cattle herds. As we attempt to meet cow requirements by increasing energy levels in rations, increased grain feeding, and decreased levels of forage have become more commonplace. 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, such as laminitis, animals can be treated, but there is no complete cure. Ruminal acidosis is something to be prevented, not repaired.

SIGNS AND NUTRITIONAL COSTS OF ACIDOSIS

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 or 5.6 (Nocek, 1997; Owens, et al., 1998), it is not enough to define ruminal acidosis as being caused by low pH. The ruminal problems can typically be traced to feeding management in need of improvement, misfeeding of highly digestible carbohydrates, underfeeding of effective fiber, or all of the above. The question is, do we recognize the signs of ruminal acidosis when we see them? 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 of individual animals
- Feces in the same feeding group varies from firm to diarrhea (feed sorting)
- 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/feed in feces
- Appearance of undigested, ground (≤ 1/4 inch) grain in feces

The bubbly manure, diarrhea, and mucin casts in particular suggest that a more extensive than desirable fermentation has taken place in the cecum and large intestine (hindgut). Ruminal and hindgut fermentations produce the same microbial products (Figure 1) and are related to the changes in fecal appearance, with excessive acid possibly being associated with the diarrhea and mucin casts. The changes in fecal consistency or long fiber particles or much apparent undigested feed can be signs that feed has passed through the rumen too quickly to be properly digested there.

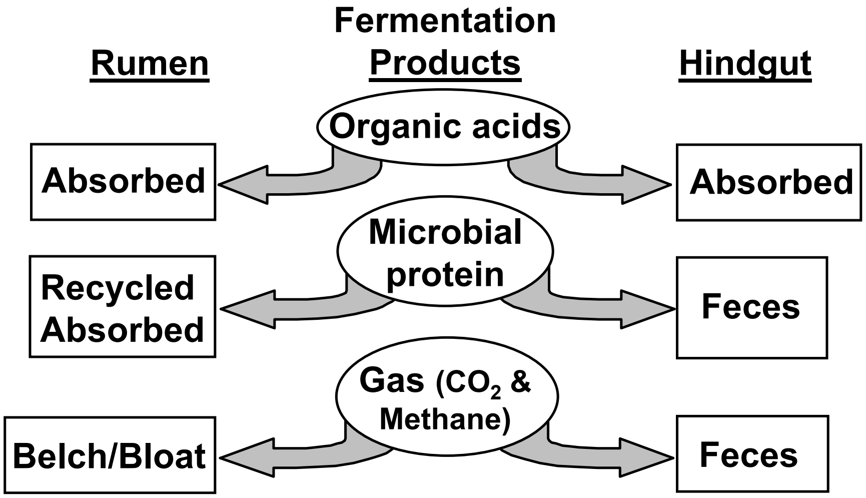


Figure 1. Microbial products and their fates in the rumen and hindgut.

Why Feeding More Grain May Decrease Energy to the Animal

If the site of digestion is shifted from the rumen to the hindgut, or if digestion is reduced, it is no wonder that feed efficiency suffers during ruminal acidosis. Undigested feed in feces is indicative of an overall reduction in digestibility of the ration. 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 and what level of production the ration can support. 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, 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.

CARBOHYDRATE FEEDING

Prevention of ruminal acidosis requires consideration of the chemical and physical characteristics of the ration, as well as herd and feed management approaches to encourage the cows to do what we want them to.

Fiber

Feeding adequate proportions and types of fiber is important to preventing acidosis, however, “adequacy” can be difficult to predict from tables. Adequacy of fiber depends not only on the amount that we offer, but on its physical form and composition, and the interaction of the cow and her diet. Perhaps to an even greater extent than for other nutrients, direct evaluation of the cow’s response is our best measure of adequacy of fiber.

Mertens (1985) 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. The 2001 Dairy NRC suggests a sliding scale of minimum NDF depending upon NDF coming from forage, and amount of nonfiber (NDF) carbohydrates (NFC) fed. 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 physically effective NDF (peNDF) in the ration. The difficulty is that there is no common agreement on a 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 peNDF system depends upon how well it describes the fiber that is actually consumed. If cows can make choices about the amounts and types of feeds they consume, any estimation of peNDF intake will be poor. Evaluating peNDF 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; the feed remaining should look similar to that which was fed. A particle size assessment of feed and weigh back should give similar values. Observation of the cows as they eat also makes clear whether they can sort, and which feeds they select for or against. A great amount of variability among animals consuming the same diet also suggests that sorting is occurring. Sorting 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 40 50% of the cows not eating or sleeping are chewing their cuds. Reformulation of the ration and feeding management need to be explored to achieve this goal.

Non-NDF Carbohydrates (NFC)

Controlling the proportions and types of NFC in the ration is essential to preventing ruminal acidosis as we strive to support good production. The NFC include organic acids, sugars, starch and soluble fiber such as pectic substances (Figure 2). It appears that different NFC differ in their digestion characteristics and potential effects on ruminal pH (Figure 3). Sugars and starch may ferment to lactic acid, which is a 10-fold stronger acid than acetic, propionic, or butyric. However, sugar (mono- and disaccharides) may not be as prone to causing ruminal acidosis as is starch (W. Kunkle and C. Fields, personal communications), possibly due to conversion of some portion of the sugar to glycogen, as opposed to its immediate fermentation (Thomas, 1960). 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 pH. Because different types of NFC differ in their effects on ruminal pH, it is reasonable to formulate rations considering NFC type, rather than just the total amount.

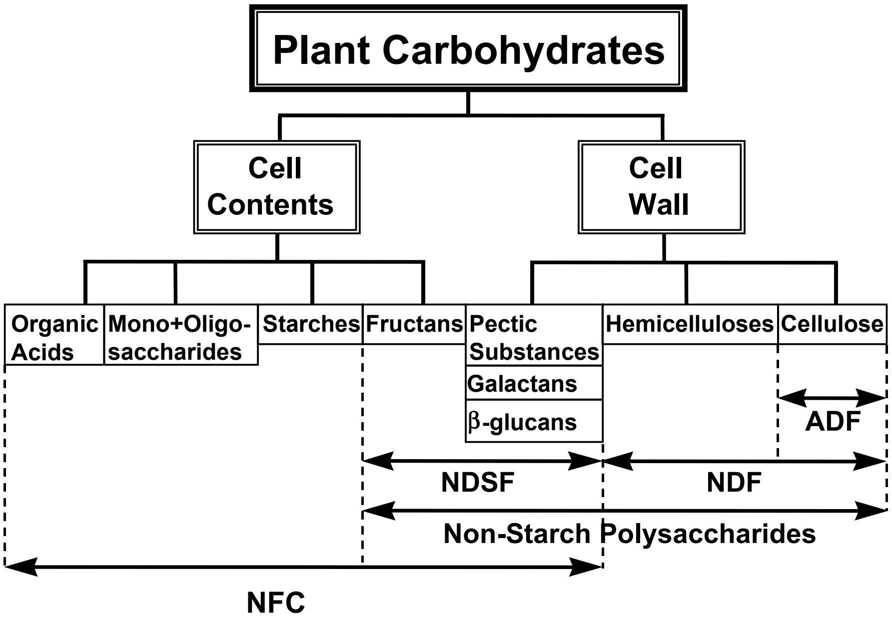
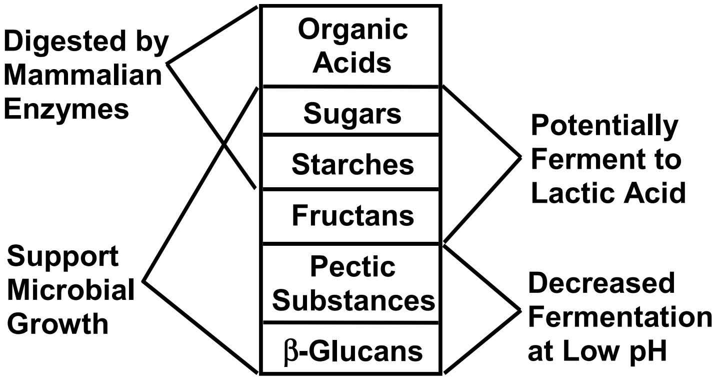


Figure 2. Plant carbohydrates. ADF = acid detergent fiber, NDF = neutral detergent fiber, NFC = non-NDF carbohydrates, NDSF = neutral detergent-soluble fiber, Sugars = mono- and oligo-saccharides. Lignin is not included because it is not a carbohydrate.



Typical Fermentation Rates
Organic acids: 0-?%/h
Sugars: +/-30%/h (?)
Starch: variable, 4 - 30%/h
Soluble fiber: 20-40%/h
(exception: soyhulls at 4%/h)

Figure 3. Nutritional characteristics of neutral detergent-soluble carbohydrates. (Note: fermentation of all carbohydrates are decreased at low pH, but the effect is more marked for NDF and soluble fiber.)

The effects of the quantities of NFC 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 produced in the rumen in a relatively short period of time. In feedlot cattle, a greater risk of ruminal acidosis was reported when more rapidly fermented carbohydrate sources such as wheat (Elam, 1976) or steam-flaked sorghum (Reinhart, et al., 1997) were 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 NFC on ruminal pH was explored with three ruminally cannulated cows in a reversal trial were fed one of two corn silage/alfalfa hay-based diets containing approximately 40% calculated NFC, 36% NDF, and 17.8% CP (Leiva et al., 2000). The diets differed in that their NFC 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 did not differ for the two diets (citrus: 6.18, hominy: 6.24; *P* = 0.52). However, the shapes of the pH by time curves differed (*P* < 0.05) (Figure 4). The pH on the

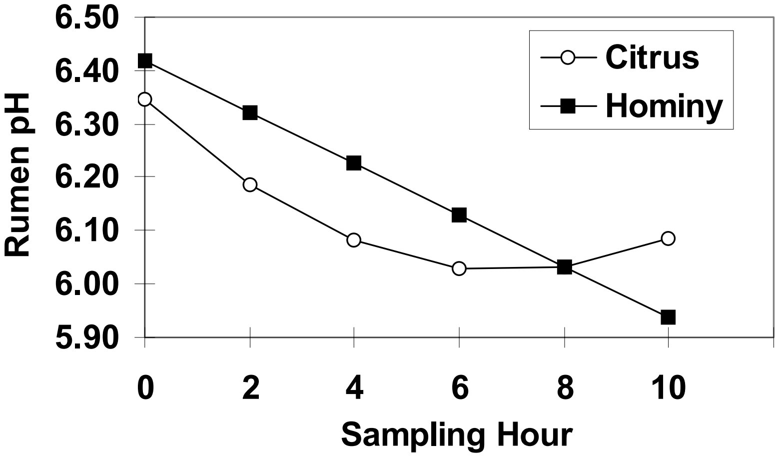


Figure 4. Regression curves of ruminal pH results for citrus and hominy rations. Hour 0 sample was taken immediately before feeding (Leiva et al., 2000).

citrus diet declined more rapidly, and reached its lowest point more quickly than did the hominy diet. The pH of the hominy diet had not reached its lowest point at 10 hours after feeding. Further trials to compare the ruminal effects of different NFC will provide information to allow more refined manipulation of ruminal pH through ration formulation.

Ration Formulation

So, how should we formulate for NFC, especially with acidosis prevention and profitable performance in mind? That is a good question, because we do not have complete information to offer complete answers – this is a work in progress. In an attempt to examine this issue, rations were obtained in a survey of U.S. lactating cow diets that supported high milk production and good health (Hall and Van Horn, 2001). The NFC values for individual feeds were estimated using calculated NFC values (100-CP-NDF-EE-Ash). The proportions of NFC as sugars, starch and soluble fiber were estimated based on feed analyses previously performed in our laboratory (Hall, 2000). The nutritionists who provided the rations indicated that cows consumed rations resembling what was on paper. Animal health can be affected by the types and amounts of NFC fed relative to amounts of forage/effective fiber in the ration, so NFC vs. forage values were compared (Figure 5).

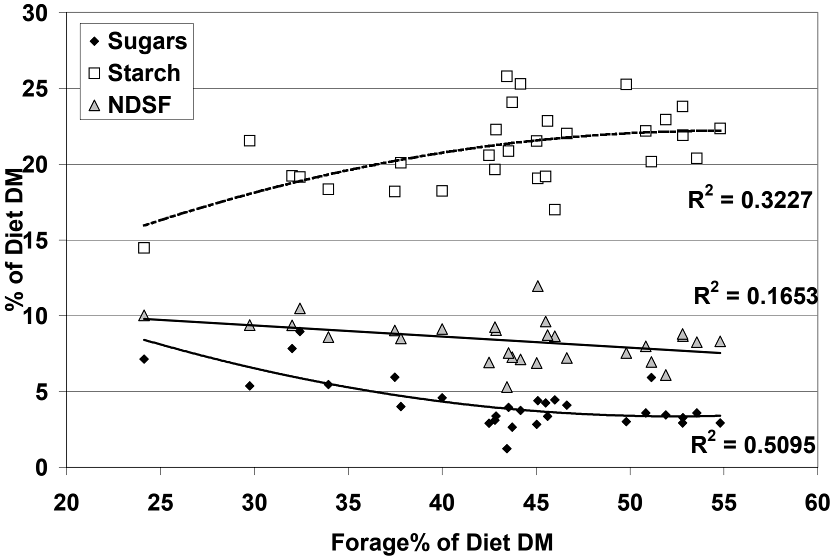


Figure 5. Estimated sugars, starch, and NDSF (soluble fiber) relative to the forage in the diets, all as % of diet dry matter. (Hall and Van Horn, 2001).

Soluble fiber was relatively constant across forage levels. Starch and sugar contents varied inversely -- as forage content increased, starch increased and sugars decreased. **HOWEVER, those changes may be a function of feeds that were available in that geographic area, rather than deliberately formulating optimal rations.** On the low forage diets, citrus pulp which contains high levels of sugar (26%) and soluble fiber (33%) was typically included in the rations, and ration starch content was low. Aside from citrus pulp, almond hulls, candy waste, some bakery waste, and molasses, there are not many sugar-rich feedstuffs available, but starch sources are abundant.

MBH Opinion/Field Observation: It appears that starch is the NFC that has the greatest potential to increase milk production, but also to increase the likelihood that an animal will suffer ruminal acidosis. The level of physically effective fiber/forage feeding seems to offer a good benchmark to initially decide how much starch to include in the ration; relatively speaking, the more forage or peNDF consumed, the more starch that may be fed. The rate of fermentation of the starch, forage types used, as well as feeding management no doubt also affect what is an acceptable amount of starch to include. Ration formulation followed by evaluation of cow response will allow nutritionists and dairy farmers to determine what is acceptable for a given feeding situation.

Possibilities To Consider:

- Starch: Appears to offer the highest microbial crude protein yield, however, feeding high levels of starch have the potential to cause ruminal acidosis and digestive upset. We need to find out the extent to which sugars and starch are interchangeable to deliver a glucose source to the small intestine, and what proportions of soluble fiber, sugars, and total or physically effective NDF to include to offset the potential for ruminal acidosis.
- Both pectins (soluble fiber) and sugars may yield less microbial protein than starch (Hall and Herejk, 2001; Sannes et al., 2002). If they yield less microbial protein, inclusion of a greater proportion of rumen undegradable protein in the ration may be appropriate as their proportions in the ration are increased.

For more information on NFC types and feed composition, visit http://www.animal.ufl.edu/hall/. Go to the "Publication" section. There are a number of articles as well as a feed composition table in the carbohydrate lab manual.

OTHER FEEDING CONSIDERATIONS WITH ACIDOSIS

Feeding Regimen

An additional risk factor for ruminal acidosis is “slug feeding” of high concentrate rations. This relates to the quantity of readily fermented NFC 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 NFC, 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 an 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 may be 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 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 6). There was an interaction of diet and temperature ($P < 0.01$). Ruminal changes 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, or shade can be used in cooling systems, but the use of water plus air movement is most effective.

The 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. Decreasing the starch content of the diet may be helpful. If the ration is palatable and contains appropriate levels of fiber and NFC, further altering the diet for heat stress may be counterproductive.

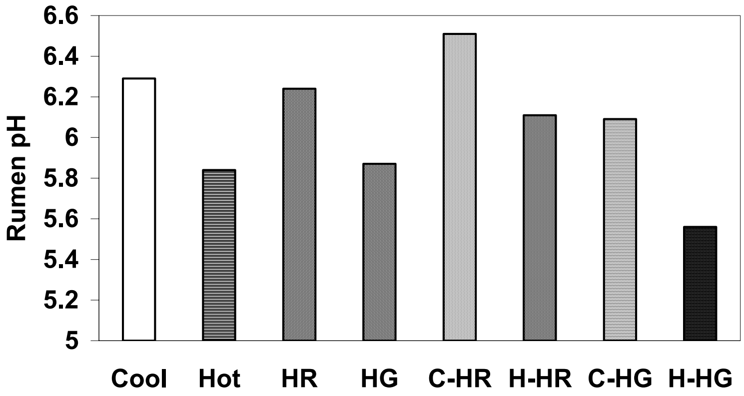


Figure 6. Ruminal pH changes with ambient temperature and diet (Mishra, et al., 1970). Cool (C) = 65°F ambient temperature, Hot (H) = 85°F ambient temperature, HR = high roughage diet, HG = high grain diet.

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