Dietary carbohydrates in heat-stressed dairy cows

Alvaro García and Fernando Díaz-Royón for *Progressive Dairyman*

Rumen acidosis results from an excessive acid load in the rumen not neutralized by salivary or feed buffers. Changes in physiology, metabolism and behavior of heat-stressed cows increase their susceptibility to both subacute (SARA) and acute acidosis. In 1970, researchers observed lower rumen pH when cows were fed 65 percent forage diets under warm, humid conditions (pH 6.1; 84.9ºF; 85 percent RH) compared to cooler, drier conditions (pH 6.4; 64.9ºF; 50 percent RH). When forage in the diet was reduced to 35 percent, the differences in ruminal pH were higher (5.6 versus 6.1 for warmer and cooler conditions). It is also important to consider how long the rumen was subjected to this acidity (i.e., hours). A drop in rumen pH below 5.6 during at least 2.5 to five hours daily has been suggested as necessary for SARA to occur.

The main changes occurring during heat stress:

- Feed intake and rumination are reduced, resulting in too little saliva to neutralize rumen acid production.
- Respiration rate increases (panting) to dissipate heat through the lungs with excess loss of carbon dioxide. Respiratory alkalosis and bicarbonate is then excreted to compensate.
- Saliva production is reduced during panting, an additional loss of buffer effect.
- Changes in feeding behavior also contribute to rumen acidosis. Cows tend to reduce the number of feeding bouts and increase the food consumed at each meal. Rumen pH declines are more pronounced with the increase in meal size. In addition, cows tend to select finer particles (concentrates) of the TMR (sorting) or reduce forage intake if feeds are offered separately.

The main herd problems observed with SARA during warm weather are a reduction in milkfat and an increase in lameness. In an experiment conducted in Florida with almost 23,000 observations, milkfat dropped from 3.85 to 3.31 percent when temperatures increased from 48.2ºF to 96.8ºF. The increase in the incidence of hoof lesions associated with laminitis occurred several weeks after cows started to suffer from heat stress. In 10 Wisconsin dairies, September was the worst month of the year for hoof lesions, with the incidence exceeding 16 percent. Opposed to the other months, lameness caused by lesions were more frequent than those lameness issues originated from hoof infections. The authors suggested that heat stress, which starts to affect cows in July in Wisconsin, could have been the cause of this increased incidence later into the fall season.

Effective fiber

As feed fermentation in the rumen generates heat to maintain constant body temperature during hot weather, one of the strategies employed by the cow is to reduce feed intake. However, other mechanisms (i.e., panting) that operate to dissipate heat actually increase the maintenance energy requirements, making it necessary for the diet to have a higher energy density. In general, nutritionists accomplish this by increasing concentrate and reducing forage in the ration. This is a sound approach; however, sufficient effective fiber should be maintained to stimulate cud chewing and rumination, thereby maintaining adequate rumen pH.

Table 1 Effects of effective fiber on milk yield and components

	Diets			
	Control	Low	Medium	High
Ingredients (%)				
Concentrates	60	60	60	60
Corn silage	40	32.4	24.8	17.2
Bermuda grass	0	7.6	15.2	22.8
Composition (%)				
NDF	30.2	33.8	37.7	42
Forage NDF	17	19.2	23.5	24.7
ADF	16	17.9	19.4	21.2
Production				
Intake (lbs/d)	40.3	39.2	38.3	36.1
Milk yield (lbs/d)	54.1	56.8	58.1	50.0
FCM 3.5% (lbs/d)	51.0	55.2	56.1	50.6
Efficiency (FCM /intake)	1.35	1.53	1.56	1.47
Milk composition				
Fat, %	3.21	3.28	3.5	3.69
Fat yield (lbs/d)	1.69	1.87	1.91	1.78
Protein, %	3.39	3.22	3.16	3.02
Protein yield (lbs/d)	1.83	1.83	1.78	1.50

FCM = Fat-corrected milk (3.5%); Source: West et al. (1999)

The National Research Council suggests the concentration of forage neutral-detergent fiber (NDF) in the TMR should be between 15 and 19 percent, depending on the amount and type of non-fibrous carbohydrates (NFC) present in the diet. This suggestion should be taken as an absolute minimum, as it was developed for TMR diets based on alfalfa of adequate particle size.

The reason why part of the diet NDF needs to come from forages is to ensure an adequate amount of effective fiber. Forage fiber stimulates rumination, and thus cud chewing, which increases saliva production that neutralizes rumen acidity. The total NDF concentration in the diet has usually been associated with the incidence of acidosis, although this correlation is not very strong. However, there is a stronger correlation of acidosis with forage NDF in the diet. In a meta-analysis of 106 diets, ruminal pH was positively correlated with the percent of forage NDF (P less than 0.0001; r2=0.63), but not total NDF.

Research has confirmed the importance of forage inclusion in diets of cows under heat stress. In a University of Georgia experiment, heat-stressed cows were fed four experimental diets having a 40-to-60 forage-to-concentrate ratio (**Table 1**). Dietary fiber concentration was achieved by partial substitution of corn silage with bermudagrass hay. Forage NDF increased gradually from 17 percent, without hay, up to 24.7 percent (22.8 percent hay) in the ration. Milk yield was highest, 58.1 and 56.8 pounds per day, for cows fed diets with an intermediate concentration of forage NDF (23.5 and 19.2 percent, respectively), while milkfat percentages increased linearly with forage NDF inclusion rate. It was necessary to include a minimum of 23.5 percent forage NDF in the diet to maintain milkfat at 3.5 percent or greater.

These results do not agree with those of 2004 researchers in heat-stressed cows fed 12 and 18 percent forage NDF diets. The concentration of forage NDF did not affect intake, but affected milk yield. Cows fed low-forage fiber diets produced six percent more milk at 84.7 pounds per day. Differences in energy density (0.79 versus 0.75 Mcal per pound for 12 and 18 percent forage NDF) likely affected production as intakes were similar between diets. However, contrary to the University of Georgia experiment, in this study, no differences were observed in milkfat, with both diets yielding 3.4 percent.

Although apparent, the positive correlation between ruminal pH and milkfat concentrations are not strong ($r2=0.39$). There are other factors, such as body fat mobilization and the quantity and type of fat in the diet, that can influence milkfat percentage and yield. As a result, a low milkfat percentage should not be considered as a definite sign of ruminal acidosis. Cows affected with SARA do not always show low milkfat concentration.

Practical considerations

The optimum NFC concentration for dairy cow diets is not well defined in the latest Nutrient Requirements of Dairy Cattle. The concentration range suggested varies between 36 and 44 percent on a dry basis. Total NFC includes starch, sugars, soluble fiber and organic acids. Because of NFC differences in degradation rate and chemical composition, different NFC sources have a different potential to reduce ruminal pH. Sugars and starch can ferment to lactic acid, which has greater effect in decreasing ruminal pH than acetic, propionic or butyric acids.

To prevent rumen acidosis, it is critical to control the amounts and types of NFC in the diet. Although the starch content recommended in dairy cow diets is between 24 and 26 percent, the starch concentration should be reduced when feedstuffs rich in digestible fiber, such as gluten feed, distillers grains and soy hulls, are included. The concentration of starch and sugars should not exceed 35 percent of the diet dry matter in order to maintain adequate ruminal pH. There should also be a minimum of 22 percent of physically effective NDF in the diet to stimulate adequate rumination and cud chewing.

The best way to achieve these concentrations of effective fiber is by maximizing forage quality. However, exercise caution with such substitutions and rebalance the diet or verify there is enough effective fiber. Substituting equal amounts of 150 RFV hay with a different hay of 200-plus RFV in a borderline "hot ration" can shift the balance and result in SARA in a herd with a previously adequately balanced ration. Using forages of high energy concentrations allow for an increase in their inclusion rate in the diet. Once the forage-to-concentrate ratio is increased, the risk of acidosis is reduced. To ensure the amount of fiber supplied by the diet is sufficient to maintain adequate rumen health, it is important to routinely monitor animals and diets. Below are some parameters to monitor in a herd or group of animals:

- *Rumen pH:* The best moment to obtain a rumen liquid sample is between five to eight hours after offering fresh TMR. It is generally assumed that a herd has no SARA problems when all animals tested (minimum of 12 from the herd or pen) by rumenocentesis have a pH equal or greater than 5.8. If the pH of one-third or more of the cows tested is between 5.6 and 5.8, or less, the group is considered at a high risk of SARA. When more than 25 percent of the animals have ruminal pHs below 5.5, the herd is considered to have SARA. It is also important to know the length of time during which the ruminal pH was below 5.6. A one-time intake of grain that dropped the ruminal pH suddenly, but only for a short time, may not be as damaging compared to low effective fiber diet that maintain acid conditions over a longer period of time.

- *Rumen activity:* In a herd with good rumen health, between 50 and 75 percent of the cows lying down should be chewing their cud. It is advisable to repeat this observation throughout the day, as most rumination activity occurs during the evening and night.

- *The incidence of laminitis* within a herd should be under 10 percent.

- *Milkfat percentage:* Values below 2.5 percent should not exceed 10 percent of the individual Holstein cows tested.

- *Manure:* In general, manure from cows with SARA is more liquid and foamy. In addition, it may contain mucous or mucin casts, fiber particles larger than 0.4 inches, bubbles and undigested grain particles. Manure can be analyzed with the NASCO digestion analyzer; according to recommendations by the Miner Institute, less than 50 percent of the manure sample should be retained in the sieves according to the distribution found in **Table 2**.

- *Particle size of the diet:* The Penn State particle size separator allows for the evaluation of particle size in TMRs. The material retained on each sieve should follow the distribution shown in **Table 3**.

The Penn State particle size separator allows corroborating if cows are selecting finer particles of the TMR. In order to do this, it is necessary to verify the uniformity of the TMR throughout the day (every six hours) and that of the refusals. The material retained in each sieve of the Penn State particle size separator should not vary more than five percentage units compared to the TMR just fed. If it does, then the cows are likely sorting the TMR.

Cows under heat stress are more susceptible to subclinical rumen acidosis. Although the use of buffers, such as sodium bicarbonate, sodium sesquicarbonate and magnesium oxide help neutralize rumen pH, they do not act upon the cause, which is a reduction in rumination and cud chewing. To maintain a healthy rumen, cows require adequate amounts of effective fiber in the diet. During periods of warm weather, it is advisable to use energy-dense forages having highly digestible fiber concentrations. In addition to diet reformulation, other measures need to be implemented that help reduce the effects of high ambient temperatures on the animals, such as forced air, sprinkler systems, etc. **PD**

Garcia and Díaz-Royón are both with South Dakota State University's Dairy Science Department.

References omitted due to space but are available upon request.

Table 2

Sieve	Sieve opening (mm)	% Retained
Top	4.76	<10%
Middle	2.38	10 - 20%
Bottom	1.59	10 - 20%

Table 3

Suggestions for TMR particle size

Sieve	Sieve opening (mm)	% Retained
Top	19	2 - 8%
Middle	8	30 - 50%
Bottom	1.8	30 - 50%
Tray	-	≤ 20