Dairy Session:

Moderators: Charlie Gardner
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Sore Feet, Sour Rumens, Clinical Quandaries

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Introduction

Clinical investigations of herds with a high prevalence of laminitis are complex. Laminitis has a multifactorial etiology. Visible signs of laminitis sometimes appear weeks or months after the inciting events. Once developed, some of the clinical signs of laminitis can remain with the cow throughout her lifetime.[14]

Ruminal acidosis is considered to be one of the primary causes of laminitis. The use of rumenocentesis as a diagnostic test by veterinarians has served to increase awareness of ruminal acidosis and has given them an ability to rule rumen acidosis "in-or-out" as a risk factor in a laminitis investigation.

For this program, I was asked to present the clinical picture of laminitis and ruminal acidosis based upon the many investigations by the Food Animal Production Medicine group at the University of Wisconsin. Because of the nature of the request, this paper will be a clinician's report including findings, observations, and opinions.

Update on Rumenocentesis

Several practical developments regarding collection procedure and sample size have emerged since the technique was described in 1994.[21]

First, we originally recommended cow restraint using sedation, hobbles, and elevating the tail (tail-jack). We no longer use sedation or hobbles. Rather, we apply a nose leader, elevate the tail, and insert the needle within 30 seconds. While this method becomes a three-person operation, it is uncommon for cows to show a visible response to the needle puncture using this procedure.

Second, our original recommendations for sample size were to test six cows in each feeding group. We now recommend sampling approximately 12 cows in any suspect-feeding group. If 3 or more of the 12 cows produce a pH of 5.5 or less, we characterize the group as having subacute ruminal acidosis (SARA). Using these guidelines, we expect that the group will be characterized correctly approximately 90% of the time.[13]

As recommended before, samples should be collected somewhere between 4 to 8 hours after a TMR meal or 2 to 4 hours after the concentrate portion of a component-fed ration.

Ruminal Acidosis / Laminitis Quandary

In 1995, we viewed laminitis as the most consistent clinical sign seen in herds with subacute ruminal acidosis.[22] While I continue to view laminitis as usually associated with ruminal acidosis, we have worked with some "acidosis" problem herds that have little to no laminitis. These have been intensively managed rotational grazing herds where the exposure of cow hooves to concrete is limited to less than 4 hours per day.

Conversely, some "laminitis" problem herds have no signs, history, and low potential for subacute or acute ruminal acidosis. However, these herds have had facilities problems that would force cows or heifers to stand on concrete for long periods of time.

Generally, we have come to view 'excess standing time on concrete' as a factor of equal importance to ruminal acidosis in laminitis problem herds.

Ruminal Acidosis Risk Factors

Ruminal acidosis is a huge risk factor for laminitis for cows in confinement systems. The following items are the primary factors in creating subacute ruminal acidosis based upon our field investigations in Wisconsin.

Ration formulation errors

The risk of rumen acidosis comes from the rapidly fermented carbohydrates of starch, sugar, and pectin. Because analyses of these non-fiber carbohydrates in feedstuffs are not readily available, ration analyses focus upon various fiber measurements that measure cell wall carbohydrates of lignin, cellulose, and sometimes hemicellulose. The National Research Council[20] (NRC) has developed recommendations for fiber content of dairy rations. Modifications of these recommendations for typical dairy rations in the Midwestern USA are found in Table 1.[27]

Table 1. Fiber and carbohydrates guidelines for diets of lactating dairy cows.

Feed component	Recommendations as a % of dry matter
Crude fiber	15-17
Acid detergent fiber	19-21
Neutral detergent fiber	27-30
Neutral detergent fiber from forage	21-22
Non-fiber carbohydrates	<40%

The NRC recommends that fiber guidelines should be modified for fiber type, particle size and distribution, total dry matter intake, bulk density of ration, buffering capacity of the forage, feeding frequency, and body condition and production level of the animal. Practices such as excessive mixing of total mixed rations and infrequent feeding of large meals increase the fiber requirement of a ration, even though the chemical analysis of the ration meets recommended nutrient densities. Our field experience suggests that it is uncommon for ration advisors to modify fiber recommendations to account for any of these factors.

Perhaps more common today than formulation errors are substitutions of unanalyzed feeds. In a dramatic herd case of ruminal acidosis, a nutritionist accidentally introduced a book value of ear corn into a series of ration formulations, but shelled corn was actually being used. Subsequently, a ration was produced that assumed that the fiber from the ears was present. Within 120 days of the substitution, approximately 57% of the herd of 120 lactating cows had developed visible signs of laminitis. In the same period, 10% of the herd sloughed the distal end of their tails for no obvious reason.

High dry matter intake

Ruminal pH is profoundly influenced by the total intake of ration. In an as-yet unpublished study where the same TMR diet was fed at different rates, mean daily ruminal pH averaged 5.7 on the high intake group and 6.1 on the group where intake was limited to 75% of the high group intake.[24] The take-home point is that as dairy genetics gives us cows capable of eating more and more feed, the risk of acidosis will continue to increase even though the same ration is fed.

Highly digestible corn silage

New systems of evaluating feedstuffs continue to emerge. Recently, various laboratories have offered *in situ* rumen fermentability tests of feedstuffs that may enhance our ability to formulate rations with greater safety.

In a recent investigation of 560 Holstein cows with a 26,000 lb Rolling Herd Average Milk, a lameness prevalence of 45% in the high and middle groups was found. A review of hoof trimmer records showed that 21% of the herd had experienced a sole abscess in the prior year. Milk fat percentage had averaged 3.5% over the past 12 months, but had ranged from 3.0 to 3.7% on a herd basis. Herd milk fat percentage had been below 3.5% on five of the previous 12 monthly DHI tests. Stalls were evaluated as excellent, but the lactating cow pens were overstocked at an average rate of 112%. Rumenocentesis showed 4 of 10 cows with ruminal pH less than 5.5. The rations met recommended fiber and starch levels and particle size and mixing was evaluated as excellent. The corn silage contained a high proportion of corn grain as evidenced by an ADF value of 19.7%. The corn silage was submitted for *in situ* fermentability analysis. The laboratory reported 3-hour rumen digestible cell contents at 3 hours of 73% and was classified as "potential for acidosis".[10] Their reported "rumen digestible NDF" at 3 hours was 7.6% of DM, whereas the target value is 2%.

The nutritionist subsequently reduced high moisture shelled corn in the diet and substituted gluten feed, thereby reducing calculated non-structural carbohydrates to an uncomfortably low 30-32% of the diet. In the subsequent two months, production has remained constant at approximately 82 lb per cow per day, milk fat % has increased to 3.6%, prevalence of lameness has gone down and the hoof trimmer reports improved scores.[7]

High fat content of TMR

High fat diets reduce the number of protozoa in the rumen. Protozoa engulf starch particles, reduce rumen bacterial numbers, retard acid production, and stabilize ruminal fermentation.[28] High levels of added fat (over 2.0 lb/cow/day) can tip a fiber-marginal ration into a problem zone.

Grain processing and moisture content

Any process that makes starch granules more available for microbial digestion increases the risk of ruminal acidosis. In most cases, increased processing increases digestibility and potential animal performance, but also increases the risk of acidosis. Fine grinding, heat and pressure treatments like steam flaking, and high moisture storage of any grain will make the ration more likely to cause acidosis than if the dry, coarsely ground form of the grain is fed.[25] Experiences of ruminal acidosis and low milk fat percentage where high moisture shelled corn exceeded 30% moisture are common.

Inadequate particle size

Forages that have been reduced to small particles will be less effective in stimulating rumination, which will result in less saliva production. For example, cows produced 0.94 ml saliva/g of fresh grass, 1.13 ml/g of silage, and 3.25 ml/g of dried grass hay.[1]

Many nutritional advisors in the US carry particle separation boxes and have made particle size analysis a routine part of their service to dairy farms. The method focuses upon the proportion of "coarse particles" in the feed, that is, particles that remain on the screen with holes of 3.8 cm diameters. General guidelines have been developed for alfalfa silage that suggest that 15-25% of the forage should remain on the coarse screen. Guidelines for corn silage are less well developed, but many advisors have a goal of 5-10% of the corn silage as coarse particles.

Similarly, the usual target for TMR samples is 7-10% of the complete ration on the coarse screen. Sometimes the TMR fails this test because of the component silages that go into the mixer, but sometimes they fail because of excessive mixing times.

Excess forage particle size that allows sorting of TMR

Occasionally, particle size of forages is so long as to allow cows to sort off the long forage particles and selective consumption of the palatable concentrate particles on the bottom of the bunk. In such cases, ruminal acidosis can occur in the more aggressive eaters who initially dominate the feedbunk. The more timid cows that eat later would receive a disproportionately large portion of forage and would not experience acidosis problems.

Irregular feeding schedules

It is common for researchers to induce ruminal acidosis by withholding feed for a period of 12 hours and then allow hungry animals to eat up to 150% of their normal day's ration. Situations where the interval between meals is increased will increase the risk of subacute acidosis. Delays in feeding occur commonly on dairy farms following machine breakdowns, labor disruptions, and sometimes mismatches between trips to the milking parlor and arrival of feed. We have a report of a herd of 400 cows in Wisconsin where one particular group of first lactation cows experienced high rates of low milk fat percentage, diarrhea, and abomasal ulcers diagnosed by either surgery or postmortem exam. The problem group frequently experienced feeding delays of 5 hours. The herd veterinarian reports that clinical cases of diarrhea and abomasal ulcer stopped and the milk fat percentage returned to 3.6% with resumption of a regular feeding schedule.[29]

Similar situations occur during hot weather when cows sometimes avoid the feedbunk during the day, but overeat in the cooler nighttime hours.[15] Subacute ruminal acidosis can occur in individual cows who may eat very little during estrus, but return to the bunk and overeat as estrus subsides. It is common for such cows to experience diarrhea and subsequent inappetence in the days following heat.

Rapid increases in barometric pressure or reductions in humidity may stimulate cows to overeat and experience acidosis. Some of these problems can be mitigated by cooling the feeding area through shading or fans, and by limiting the amount of increase in feed delivery per day.

Reduced forage dry matter intake because of failure to monitor changes in moisture content of feeds in TMR

Deviations from the desired ration nutrient content commonly occur because of failure to adjust for changes in the moisture content of forages. Our field experience suggests that a minority of TMR operators monitor moisture of forages on an at-least weekly basis. A majority of dairy operators do not monitor moisture, but observe the rate at which cows clean up the bunk and adjust the forage weight of the next batch. In the upper Midwest, the predominant forage is alfalfa haylage. If cows clean up the TMR feeding quickly, the weight of as-fed haylage is increased in the next batch mix. Conversely, if TMR is left, forage is reduced in the following batch. The practice is conceptually correct if the observed change in consumption is due to dry matter changes in the forage. However, if the change in consumption is due to anything other than the forage dry matter, the subsequent adjustments are incorrect. If the group of cows reduces its DMI and the dairy operator subsequently reduces haylage in the TMR, the ration usually becomes fiber deficient. Routine monitoring of the dry matter content of feed ingredients is an important task of TMR management.

The usual objection to monitoring forage dry matter is the time required to perform the test. Dairy extension services commonly recommend the use of a microwave oven for the determination. Oetzel *et al*[23] have compared a variety of methods. The use of an electronic meter (1210 Silage Tester; Farmex Inc., Aurora, OH) required the least operator skill and time, and accuracy was acceptable for haylage and high-moisture shelled corn. The electronic tester can help overcome objections to performing the test and reduce the risk of inappropriate TMR adjustments.

Inadequate transition from dry cow to lactation ration

As smaller dairy herds in the upper Midwest have increasingly adopted total mixed rations, it has become a common practice to prepare one ration for the entire lactating herd. The single lactation TMR has made difficult the gradual introduction of concentrates to individual fresh cows in the weeks after calving. The single TMR can create acidosis problems for unadapted fresh cows and is necessitating the creation of transition rations between the dry cow and lactation ration.

Guidelines for maximal acceptable change between rations are scarce. Recommended exist that the net energy of a ration can be safely increased about 10% at a time.[9] For example, a change from an energy density of 0.70 mcal/lb to 0.77 mcal/lb would be viewed as safe. National Research Council recommended dry cow rations would have 0.58 mcal/lb and many lactation TMR rations have 0.78 mcal/lb.[22] Observation of the 10% guideline would require two intermediate rations.

However, practical experience suggests that most dry cow rations exceed 0.58 mcal/lb. The issue is not how many rations are fed. Rather, the issue is how great is the change. For example, if the early dry cow ration is estimated at 0.65 mcal/lb, a single intermediate ration accommodates the 10% guidelines.

Excess grain in early post-partum phase with component-fed rations

For years, dairy operators have been told to minimize the "negative energy balance" of early lactation and have attempted to maximize concentrate intake in early lactation. Field recommendations for the feeding of component-fed concentrates during the first three weeks are commonly excessive. For example, it is common to find cows fresh 7 days consuming 20 lb of dry matter from concentrates. Rations like these rarely meet the NRC fiber guidelines for early lactation cows because very little additional forage will be consumed. Cows at week one post-partum may be consuming only 30 lb DMI according to DMI prediction equations published by Kertz *et al.*[17] Table 2 lists daily DMI for two example cows at each week post-partum for four weeks. Unlike the traditional prediction equations for DMI, these equations address the dynamic changes in intake in the immediate post-parturient period.

Competitive feeding systems that put timid animals in a competitive situation for forages

Some component feeding systems deliver forages in a competitive bunk area, but offer concentrates in individual stalls. This can place younger, timid cows at risk as they can consume full feedings of concentrates, but less forage than needed.

Table 2. Dry matter intake predictions.

Week post-partum	First lactation, 1200 lb BW[a], DMI, lb/day	Later lactation, 1350 lb BW[b], DMI, lb/day
1	28.5	33
2	32	37.5
3	35	40.5
4	36.5	43

[a]First lactation cow expected to peak at 79 lb of 3.5% fat milk

[b]Mature cow expected to peak at 100 lb of 3.5% fat milk

Excessive interval between concentrate and forage meals

Field investigators have long recognized the special risks of acidosis of component-fed rations. The risk of acidosis is reduced if the concentrate portion of the ration is 3 or 4 smaller portions per day, rather than larger portions delivered in two feedings. Of particular danger is the practice of feeding grain in a stanchion barn prior to the morning milking without access to forage.

We investigated a herd with a complaint of a 40% prevalence of laminitis, diarrhea, high cull rates, and low production. In this case, grain was fed in two feedings per day just prior to each milking. Forages were fed at an outdoor bunk of inadequate length that could accommodate only half of the herd. About half of the herd had access to alfalfa haylage immediately following milking but the remainder remained in the barn without forage for approximately 3 hours following the grain meal. Subacute ruminal acidosis was diagnosed in the group in the barn whereas the group that received the early forage was normal. The herd problem was resolved with an extension of the bunk and early access to forage following milking.

Ruminal Acidosis Does Not Always Result in Laminitis

We have worked repeatedly on an intensively managed rotational grazing herd of 120 cows over the past several years. In 1997, the herd manager complained of disappointing milk production and frequent episodes of diarrhea in the herd. Since the previous season, peak milks had declined from 90 to 82 lb for older cows and from 70 to 59 lb for first lactation cows. Herd average ME Milk had declined from 19,000 lb in 1996 to approximately 17,000 lb in 1997. On the date of the farm visit in late June, the average cow was 80 days-in-milk and was producing 60 lb

Table 3. Results of herd testing.

Tests completed	No. samples	Average	Range
Body condition score	15	2.5	2.0-3.0
Serum urea nitrogen	6	15	10-20
Rumen pH	11	5.45	5.0-5.8

of milk of 2.9% fat and 3.0% protein. Examinations and testing of the cowherd are reported in Table 3.

Body condition scores were low, urea nitrogen was considered normal, and 6 of the 11 cows tested showed rumen pH values below 5.5. Herd-based subacute ruminal acidosis was diagnosed. Within days, the herd showed a positive response to nutritional interventions with increased milk, increased fat percent, and reduced frequency of diarrhea.

The important point from this investigation is that there was almost no lameness in the herd. While the rumen pH values were as low as we find on investigations, only 3 of the 120 cows showed any abnormal gait. We have had similar findings in two other investigations of grazing herd ruminal acidosis. Our interpretation is that if the cows stand and walk on an earthen, cushioned surface, the degree of ruminal acidosis needed to trigger laminitis must be more severe than if the cows have significant exposure to concrete.

Excess Standing Time on Concrete

Veterinarians have recognized for years that exposure to hard surfaces is a contributing factor in laminitis. Greenough and Vermunt have used the term "overloading laminitis" to describe the phenomena. While several anecdotal reports can be found, a report by Colam-Ainsworth *et al*[6] of an English dairy with two 130-cow dairy units is particularly compelling. Both facilities were identical with the exception of manure handling systems, as the facility constructed last had a liquid manure handling and storage system. Replacements were raised in common facilities. Feeds were produced on common fields. Ration management was identical. Yet the second barn experienced annual laminitis rates in lactating heifers of 47 to 70% during its first four years of operation, while the first barn experienced no lameness. When moved from the problem barn to the normal barn, lame heifers usually recovered.

A thorough investigation of the two facilities was reported including a summary of animal behavior observations as presented in Table 4.

Stalls, ventilation, and feeding facilities were essentially identical. Because of the manure handling system, the problem barn used one-fourth the volume of bedding per stall as the normal barn. The report notes that bedding usage met "ADAS" quantity recommendations in the problem herd, but did not exceed such recommendations. Identification of the differences in stall usage behavior differences and bedding rates convinced the manager to increase the bedding to equivalent amounts. The laminitis problem disappeared from the problem barn.

Table 4. Behavior during repeated 2 hour observation periods.

Behavior	Problem Barn	Normal Barn
% standing at observations	50-55	25-35
% lying down for entire period	32	65
% lying within 10 minutes of entering barn	29	70

The clinical issue appeared to be the proportion of time spent standing on concrete. While the bedding in the stall is a factor, it is only one part of a complex interaction between facility and stall design, maintenance.

Factors That Affect Standing Time On Concrete

It may be useful to consider a "day in the life of a hoof" as consisting of resting time when it bears no weight, time standing or walking on cushioned surfaces, and time standing or walking on concrete or other hard surfaces. A combination of facility design and management factors determines the amount of time that a cow spends in on each surface. The primary factors appear to be stall availability, comfort of the stall itself, access to feed, time spent in travel to and from the milking center, as well as time in the holding area and parlor, and access to softer surfaces such as outdoor earthen lots or bedded packs.

When investigating herds with a high prevalence of laminitis, it is important to remember the long duration of the hoof lesions and carry the investigation beyond the milking herd. It is not uncommon to find that a herd-laminitis problem has begun in the pregnant heifer groups and the inciting factors in the heifer rearing facilities.

Stall availability

It has become common for managers of freestall dairies to overstock the barns by introducing more cows than there are stalls. In a study of groups with 100% and 130% stocking density, Batchelder[2] reported that all of the stalls were filled frequently in the overstocked group and that cows spent more time standing in the alleys waiting for an open stall than they spent eating in the overstocked pen. He also reported that cud chewing was observed in 28% of the overstocked cows and 37% in the normal stocked group. Reduced cud chewing would likely reduce saliva production and could also increase the risk of ruminal acidosis.

Stall comfort

It has become clear that resting time and stall usage increases when the stall surface is well cushioned and is sized so that the cow can enter, lie down, and rise without hindrance. A system to evaluate dairy cow stalls follows on subsequent pages.

Time in holding area and parlor

There is a traditional target of sizing the pens and holding areas so that cows spend a maximum of 1 hour in the holding area per milking (45 minutes if milked 3 times per day).[4] Another recommendation is to design the milking center so that cows spend a maximum of 3 hours per day in the holding area and parlor.[19] Regardless of parlor design, the efficiency of individual workers, the preparatory routines, the production level of the cows, and the degree of cleanliness of the cows entering can have a major effect on the total time that cows spend in the holding area.

The distance that cows travel on concrete lanes to and from the milking center can become substantial in large herds. Some herds have installed cushioned mats down traffic lanes and observe that cows line up to walk on the softened surface to and from the milking center.

Availability of feed

The unproven assumption is that the more accessible the feed, the less time a cow will need to stand to consume it. Modern freestall barns have either 2 or 3 rows of stalls and a single feeding surface approximately as long as the row of stalls. The 2-row configuration allows a larger proportion of cows to eat at once and should reduce the amount of time extra cows stand waiting for a chance to eat.

Access to earthen lots for exercise

Experience in several field investigations suggests that access to outside earthen lots or pastures will substantially reduce the risk of laminitis in situations where we would otherwise expect laminitis disasters.

A System to Evaluate Dairy Stalls

We have devised a system to evaluate stalls based upon four points. Dairy cow stall design should provide for four functions: a comfortable surface to lie on, adequate platform space for the resting cow's body, "lunge and bob" room during rising, and adequate neck room to complete rising.

Surface cushion

The stall should have a soft, moldable surface from front to rear. Bedding should be dry and deeper than 4 inches. Because of minimal opportunity for bacterial growth, sand is preferred, followed by shavings and sawdust, sunflower hulls, chopped straw, shredded newspaper, and long straw in unranked order.

Bedding placed on top of a flat platform gets dragged off, making the rear platform hard, uninviting, and a factor in development of rear hoof laminitis, hock calluses and crushing teat injuries. Bedding retainers made of PVC pipe can be retrofitted on flat platforms. Mattresses filled with shredded rubber can provide an adequate cushion over stall surfaces. Bare concrete and unbedded rubber mats are unacceptable surfaces for the humane housing of cows.

Adequate and defined resting space

The platform from the rear edge of the stall to the area of the brisket board (or stanchion) must accommodate the cows' body. Where cows choose their stalls, the stalls should be sized to fit the average of the biggest 25% of the group using the stalls. Calculated body lengths for animals of various weights and girths are presented in Table 5.

The space should be defined in front by a brisket board that extends no more than 6 inches above the bedded surface of the stall.

Table 5. Estimated relationship between body weight, girth, and required resting stall length.

Body weight, lb (kg)	Chest girth, in (cm)	Body length, in (cm)
900 (408)	68 (172)	55 (140)
1000 (454)	70 (179)	57 (144)
1100 (499)	73 (184)	58 (148)
1200 (544)	75 (190)	60 (152)
1300 (590)	77 (195)	61 (155)
1400 (635)	79 (200)	63 (159)
1500 (680)	80 (204)	64 (162)
1600 (726)	82 (209)	65 (165)

Stall width should be 48 inches (1.2 meters) for cows greater than 1050 lbs (475 kg). If cows weigh less than this, the stalls should be 44 inches (1.1 meters) wide.[5]

"Lunge and bob" room when rising

Total stall length should accommodate the body space requirement for the cow plus the headspace required for rising. Photographic analysis of cows rising on pasture indicates that a forward lunge space of 27-39 inches (0.7 to 1.0 meters) is used in the rising movement.[5] The area in front of the brisket board should allow for this forward lunge and be free of low obstructions to allow the head to "bob" during the lunge.[11] For example, a mature 1500 lb (680 kg) Holstein cow would need 64 in (162 cm) resting area plus 27-39 in (70-100 cm) lunge area for a total stall length of 7.5-8.0 ft (91-103 cm). The high end of the range allows a full forward lunge space for all cows.

The author has seen repeated examples of poor freestall usage where forward lunge space was adequate, but the cows could not "bob" their head downward because of excessively high brisket boards or excessive sand piled in the front of the stall. It appears that any obstruction greater than about 10 inches above the bedded surface interferes with the rising motion of some cows.

Free stalls of deficient length can be modified in three ways. Sometimes, openings can be cut in the front of some stalls so cows can extend their heads forward through the barrier. The most common adaptation of short stalls is a cantilevered "wide-span" divider where the lower bar is no higher than 11 inches off the surface of the bed and the upper bar is at least 40 inches above the bedded surface, allowing the cow to lunge between the two bars into the adjacent stall. Another stall dividers for short stalls is cantilevered with the lower bar eliminated or bent upward in the anterior area of the stall (Michigan-style, Dutch comfort, etc). For adult Holstein cows, there should be at least 32 in of space below the bar for the cow to successfully lunge into the adjacent stall.

Neck room to rise without obstruction

The neck rail should be located at a height 6-10 inches (15 to 25 cm) below that of the withers[5] so that a cow can rise without hitting it. It should be positioned directly above the brisket-board. As measured from the rear curb of the stall, the neck rail should be positioned forward and above a distance equal to the resting body length as described above. While the neck rail limits forward movement of the cow, it is less effective than the brisket board in controlling fecal and urine contamination of the stall.

Summary

Laminitis has a complex etiology. In herds with a high prevalence of laminitis, the primary factors to rule out include subacute ruminal acidosis and excess standing time on concrete. Each of these factors can result from any of a number of management practices, decisions, and accidents. Thorough evaluations of rations, feeds, rumen fluid, feed delivery schedules, cow and heifer facilities and groupings, and milking schedules can identify problems and solutions.

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