Diagnosis and Management of Rumen Acidosis and Bloat in Feedlots

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INTRODUCTION

Most beef cattle in North America are raised on pasture for most their lives and then are finished in a feedlot on a high-concentrate diet composed of cereal grains such as corn, wheat, or barley. Economics favor a grain-finishing production system because of several factors, including reduced cost per unit of energy and resulting improved growth efficiencies associated with grains compared with roughages; availability of grains and land; logistical, storage, and operational efficiencies of transporting and handling grain; and the quality and flavor aspects of beef produced from grain-fed cattle. The rumen is remarkably adaptable to

KEYWORDS

• Acidosis • Bloat • Feedlot • Diagnosis • Rumen

KEY POINTS

• Ruminal bloat and ruminal acidosis represent the most common digestive disorders in feedlot cattle.
• Prevention of digestive disorders focuses on proper grain adaptation, sufficient ration fiber, ionophore inclusion, and minimizing feed variation.
• Diagnosis of digestive disorders should include a thorough feed and treatment history, evaluation of animals in their home environment, and complete necropsy.
• Treatment of digestive disorders depends on the specific digestive disorder and severity. A large number of animals may be affected so triage becomes critical to minimize impacts.
• Numerous animal and operational variables determine the digestive disorder prevalence, preventive techniques, treatment options, and overall impacts of digestive disorders in the feedlot.

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digest both forage and grain, and health challenges are common to cattle in each production phase. During the traditional feedlot phase of production, digestive disorders such as acidosis and bloat can result from the rapid fermentation of grain in the rumen. Understanding contributing causes and management factors that can help mitigate these potential maladies is important in order to optimize cattle production and health.

PREVALENCE OF DIGESTIVE-RELATED MORTALITY

Compared with other causes of mortality in the feedlot, digestive-related mortalities comprise 19.5% to 28.4% of all mortalities. An internal database was examined that represented 4,487,364 head of cattle marketed between the years 2014 and 2016 in 11 feedlots ranging from southern Idaho to southern Arizona. In these feedlots and over this time frame, digestive mortality represented 0.073% (percentage of monthly occupancy) with a range from 0.064% (2016) to 0.082% (2015). In addition, digestive mortality accounted for 26.9% of all mortalities with a range of 25.3% (2016) to 28.4% (2015). This prevalence was similar to that found by Vogel and Parrott, who reported an average monthly digestive mortality of 0.06% (range, 0.05%–0.08%) and digestive mortality comprising 25.9% of all mortalities. In a more recent publication by Vogel and colleagues, an analysis was performed from an industry feedlot database with closeout records from 2005 to 2014. This analysis revealed that 19.5% of mortalities were digestive related, with a range of 0.039% to 0.049% monthly digestive mortality, and the average day-on-feed at death was day 99. In addition, digestive mortality tends to be positively correlated with days on feed and with the beta-agonist feeding period. Anecdotally, the investigators have observed that Holsteins and cattle housed in feed yards at higher elevations are more at risk of bloat. In addition, it has been observed that cattle in feedlots north of 38° north latitude have a higher prevalence of digestive mortality. This finding could be a function of genetics, weather, or other factors associated with more northern latitudes.

An analysis of mortalities diagnosed as bloat or acidosis provides the relative contribution of each diagnosis to total digestive-related mortality. From the years 2014 to 2015, 96.3% of all digestive mortalities were diagnosed as bloat compared with 3.7% diagnosed as acidosis. From a mortality standpoint, the contribution of bloat to digestive-related mortality represents most cases.

RUMINAL ACIDOSIS REVIEW

Ruminal acidosis in feedlot cattle can occur when rumen osmolality increases because of accumulation of lactate, short-chain fatty acids (ie, volatile fatty acids [VFAs]), and glucose. As a result, rumen pH decreases and the body reacts in a protective fashion by reducing feed intake and reducing acid absorption. Lactate accumulation predominates in acute acidosis from the increased rate of production of glucose and reduced use of glucose, causing lactic acid–forming bacteria to proliferate. The significance of ruminal lactate concentrations in subacute and acute acidosis seems to differ. Researchers have indicated that concentration of total organic acids is of greater significance in subacute acidosis and lactate may be of greater significance in acute acidosis. As a result of ruminal acid accumulation, the ruminal osmotic pressure exceeds that of blood, resulting in a concentration gradient and a net flux of water into the rumen. This high osmotic pressure and influx of water can cause diarrhea and dehydration as well as damage to the rumen epithelium causing rumenitis (Fig. 1).

During repair, the rumen wall can be thickened, and ruminal papillae can be altered, resulting in parakeratosis. This resulting damage to the rumen epithelial wall can
increase permeability, which can have long-term effects on both nutrient and toxin absorption. The rumen microbial population also changes with the changing rumen pH and with increased lactate accumulation so that lactate producers such as *Streptococcus bovis* and *Lactobacillus* spp proliferate and protozoa and cellulolytic microbes decline. Entodiniomorph protozoa are known to engulf and sequester starch and ferment it at a slower rate than bacteria; however, the reduction of these ciliates during acidosis may provide for a less stable rumen environment. The altered microbial composition, reduced salivation, and reduced ruminal pH can also decrease fiber digestibility, which can exacerbate the issue further.

Endotoxins such as lipopolysaccharides and amines such as histamines can also be released from microbes because of the lysis of microbial cells that occurs at low pH, and these are then absorbed more easily across the damaged rumen wall. These products, along with the damaged rumen epithelium, can affect rumen motility and can contribute to other ailments associated with acidosis, such as bloat, laminitis, liver abscesses, polioencephalomalacia, and death. If the rumen pH cannot be equilibrated, the acids will be absorbed into the blood. Consequently, if the bicarbonate buffering capacity of the body is overwhelmed, systemic acidosis can result.

**CLINICAL FINDINGS**

Ruminal acidosis can vary from a mild indigestion to subacute acidosis to an acute and often fatal metabolic acidosis. When acidosis is suspected, a thorough history should be collected, including ration composition, milling records, and feed records. In addition, feed transition schedules and feed step-ups can aid in understanding the risk of ruminal acidosis. Severity of ruminal acidosis is a function of time below a specified threshold pH (5.2) and magnitude below the threshold. Animal variation also exists in tolerance to acidosis, as shown by intraruminally placed pH meters and challenge models. In cases of mild or subacute ruminal acidosis, cattle may show signs of colic and anorexia, and loose stools are commonly present. When an entire group of animals is affected, it is common to see a reduction in feed intake, and, as the home pen surface is evaluated, stools will be seen across the surface that have a shiny appearance and are mostly liquid. In addition, cattle commonly have an abnormal amount of manure smeared across their hindquarters. Mild or

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**Fig. 1.** The cause of acidosis in cattle. (Adapted from Owens FN, Secrist DS, Hill WJ, et al. Acidosis in cattle: a review. J Anim Sci 1998;76(1):277; with permission.)
subacute acidosis is commonly seen during ration transitions, weather alterations, and mild feeding errors.

In severe cases of ruminal acidosis, the first indication of a problem is often a large decrease in feed consumption noticed by the feed caller. In addition, pen checkers notice cattle showing clinical signs consistent with ruminal acidosis. Cattle may be recumbent, some may be staggering, and severe anorexia is present. Recumbent animals often lie with their heads tucked in their flanks, similar to parturient paresis. Further examination reveals an absence of ruminal contractions, diminished or absent palpebral reflexes, severe dehydration, and animals that are severely lethargic. A profuse and malodorous diarrhea develops and grain is typically present in the stools at an abnormal quantity from the increased rate of passage and decreased digestibility.

Postmortem examination at the time of death reveals severe dehydration (eye recession), copious amounts of fluid in the gastrointestinal tract, and a low ruminal pH (<5.0). The mucosa of the ruminal papillae is brown, friable, and easily detaches, revealing a diffuse and severe rumenitis (Fig. 2). Ruminal contents have an increased proportion of fluid and undigested grain and a sour smell.

**TREATMENT**

Once a presumptive diagnosis of acidosis has been made, the current feed should be evaluated and bunk scooped or ration altered to prevent cases from progressing or new cases developing. Cattle that are recumbent have a guarded to poor prognosis. Severely compromised cattle should be humanely euthanized.

Standing cattle should be offered grass hay and water and monitored until they are stable. Systemic antimicrobials, nonsteroidal antiinflammatory drugs, thiamine, fluid support, and oral magnesium hydroxide are often beneficial to address the varying effects of the insult. Limited research is available on stepping cattle back up to a

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**Fig. 2.** Acute acidosis. Note the sloughing of the ruminal papillae revealing a diffuse and severe rumenitis.
finisher ration after an acidotic bout. It is common to wait a week after the initial insult and then begin a slow ration step-up program.

Laminitis, polioencephalomalacia, and liver abscesses are sequelae that can occur in cattle that recover from rumen acidosis. It is also the investigators’ observation that cattle performance is severely affected following a severe acidosis insult and rarely does the animal or pen return to previous intake and performance. Salvage slaughter should be considered for cattle that do not respond to treatment or have a poor recovery.

RUMINAL BLOAT REVIEW

Bloating (ruminal tympany) results when excess gas accumulates in the rumen, resulting in increased intraruminal pressure and distention of the left dorsal abdominal wall, becoming apparent with protrusion of the paralumbar fossa area. Ruminal fermentation of feedstuffs by microbes generates gases, primarily carbon dioxide and methane. These gases are expelled from the rumen by absorption through the rumen wall, passage through to the next stomach compartment, or eructation through the esophagus; eructation through the esophagus is the predominant route for gas expulsion from the rumen.33,34

Eructation is a complex process involving integration of numerous organs by the central nervous system.33 Ruminants use organ reticulorumen contractions to mix contents and for eructation. The primary contractions consist of 2 contractions of the reticulorumen fold and then a contraction that moves caudally. Eructation is associated with the secondary contractions and comprise contractions of the dorsal coronary pillar, caudodorsal blind sac, and dorsal sac, and relaxation of the caudoventral blind sac.35 Contraction of the longitudinal and cranial pillars prevent digesta from filling the cranial sac and allows free gas in the dorsal sac to be expelled from the cardia. The multiple-stage eructation event is induced by increased ruminal gas and fill pressure, which is sensed by tension receptors located in the reticulum and cranial sac of the rumen.35,36 The information from the tension receptors is transmitted via the afferent vagus nerve fibers to the central nervous system. If the distention is severe, then ruminal contractions are inhibited and result in ruminal atony.37 During eructation, gas passes out of the rumen through the cardia into the esophagus and then pharynx. As the nasopharyngeal sphincter is closed, the gas is forced through the trachea and then into the lungs, where some gas is absorbed and the remainder exhaled.33,36

If the rate of gas production exceeds the rate of elimination, then bloat can result. In extreme situations, the increased gas accumulation and resulting ruminal distention can exert pressure on the diaphragm and lungs, which can inhibit respiration and may result in death by asphyxiation if not alleviated. Bloat can occur in cattle grazing pasture or in cattle housed in a feed yard and can occur in the forms of free-gas bloat or as frothy (foamy) bloat. Free-gas bloat usually results from one of the following causes: a physical obstruction (eg, potatoes, beets, hay twine) anterior to the rumen; damage to tissue such as the vagus nerve, cardia, or rumen; or changes in rumen motility.34,36,38,39 Although not as common, free-gas bloat can also occur during lateral recumbency or be caused by hypocalcemia, acid indigestion, or esophageal stenosis from lesions, tumors, or inflammation.36,40 If observed and diagnosed in a timely manner, free-gas bloat can typically be alleviated quickly by removing the obstruction from the esophagus or by intubating the rumen to expel the gas. In many cases, free-gas bloat arising from damaged tissue can become a chronic, recurring issue.
The predominant type of bloat in feedlot cattle is frothy bloat.34,37 The rumen contents of feedlot cattle are normally stratified by the density of digesta, with the smaller and denser particles in the ventral rumen progressing dorsally to longer, less dense particles and then a gas layer in the dorsal sac that forms as gases produced by microbial activity rise as bubbles through the digesta.41 Frothy bloat arises when a stable foam forms and then traps gases throughout the fluid phase of the rumen so that the digesta are less stratified.38 The foam can be very persistent and can occupy the entire reticulorumen. The increased volume of rumen digesta can potentially impair the clearing of the cardia and inhibit eructation of gases.33

The formation of a stable foam is thought to be related to the release of excess stored mucopolysaccharides (or slime) from encapsulated rumen bacteria, release of other molecules including nucleic acids and carbohydrates during lysis of rumen microbial cells, and digestion of feedstuffs.41–44 The increased quantity of nucleic acids and carbohydrate increases the viscosity of rumen fluid and is characteristic of feedlot bloat.43–46 Saliva has been shown to have antifoaming characteristics.47,48 Specifically, it was postulated that salivary mucin may be an antifoaming agent, and researchers showed that catabolism of mucin by mucinolytic bacteria was associated with bloat.49 Consequently, decreased saliva production may be correlated to bloat occurrence.

Acidosis and bloat are interrelated disorders, and bouts of acidosis can predispose cattle to bloat. Ruminal contractions and motility are reduced by lactic acid, VFAs, endotoxins, and histamines, levels of which have been shown to increase during acidosis.25 Some consequences of acidosis and increased rumen osmolality include decreased salivation, reduced rumen and intestinal motility and absorption, increased lysis of microbial cells, a change in the rumen microbiome, and decreased bacterial digestion of starch and fiber.6,8,25 Altogether, rumen stasis and stagnation and reduced abomasal motility can cause gas to accumulate in the rumen and can lead to bloat.

**CLINICAL FINDINGS**

Primary ruminal bloat is one of the more straightforward diagnoses to make. In early stages of the disease, the left paralumbar fossa is mildly distended and abdominal distention is present. As bloat progresses and intraabdominal pressure increases, the distention in the left paralumbar fossa becomes more apparent, the rectum may protrude, and pressure on the diaphragm increases until the animal shows signs of respiratory distress, and a reluctance to move (Fig. 3).

In addition to clinical signs, other factors can aid in a presumptive diagnosis of bloat. In the feedlot, peak prevalence occurs at 99 to 120 days on feed,1,2 and is seen most frequently during ration changes, weather alterations, and following variations in milling and feed delivery. During a bloat event, many of the factors that trigger bloat affect the entire group so it is common to see a range of clinical severities within a group from mild to moderate abdominal distention to clinical bloat.50

A thorough individual and pen-level history should be collected at the time of death. In addition, noting the location and presentation of the animal at death and timely necropsy aid in an accurate diagnosis. Non–digestive-related causes of bloat mortality such as cast and a prolonged period from death to the time of necropsy may have identical postmortem lesions to bloat. A complete postmortem examination should be performed, examining all major organs and ruling out other causes of death.

Gross necropsy findings associated with bloat may include, but are not limited to, (1) congestion, hemorrhage, and edema of the anterior portion of the carcass, especially
in the area of the cervical muscles; (2) pallor of the semimembranosus and semitendinosus muscles of the hindquarters; (3) edema, often with emphysema between the muscles groups of the hindquarters, scrotum, and area of the mammary gland; (4) small and pale liver; (5) compressed lungs; and (6) presence of a tenacious froth or gas in the rumen.50–52

**TREATMENT**

Passage of a stomach tube is indicated for the initiation of the treatment of abdominal distention. The largest-bore tube of sufficient length to reach the dorsocaudal ruminal sac should be passed. Attempts should be made to clear the tube by blowing and the tube should be moved back and forth within the rumen to locate areas of gas that may be relieved.⁵⁰ If no gas is present, the tube should be removed and presence of froth within the tube should be examined. If the animal is not in respiratory distress or extremely colicky, surface-active agents such as mineral oil or dioctyl sodium sulfosuccinate may be administered.

Severely compromised animals require surgical intervention. A trocar and cannula in the left paralumbar fossa should be used to initiate immediate relief. With frothy bloat, a standard size instrument is often not sufficient, so a larger-bore (2.5-cm diameter) instrument or rumenotomy should be performed.⁵⁰ Salvage slaughter is a humane option for cattle that fail to respond to treatment and chronically bloat.
RUMINAL DIGESTION OF GRAINS AND FORAGES

Grains and forages are ingested, and the starch and fiber components within each feedstuff are digested by rumen microbes to form short-chain fatty acids (VFAs), including acetate, propionate, and butyrate. In addition, lactate and gases such as carbon dioxide, methane, hydrogen, nitrogen, oxygen, and hydrogen sulfide can be byproducts of ruminal digestion. The short-chain fatty acids are then absorbed through the rumen wall and are used by various tissues for production of glucose, fatty acids, and ketones. Grain processing methods such as steam flaking or rolling or grinding followed by fermentation, which results in high-moisture corn, are commonly used to help solubilize the protein matrix surrounding the starch molecules in the kernels, which then makes the starch more available to rumen microbial action, thereby increasing the efficiency of starch use. The cell wall components of forages such as cellulose and hemicellulose are digested more slowly than the starch in grains. This difference in the rate of digestion can potentially result in digestive and health challenges such as acidosis and bloat.

FACTORS AND MANAGEMENT CONSIDERATIONS AFFECTING ACIDOSIS AND BLOAT

A key challenge in management of digestive disorders is the acute to peracute nature of the disease resulting in failure to detect and treat in a timely manner. Records show a low level of detected morbidity attributed to bloat and acidosis compared with a high mortality.²,31,53 The National Animal Health Monitoring System estimated that 71% of feed yards surveyed were affected by digestive problems, and the respondents only observed digestive-related issues in 4.2% of the cattle.⁵³

Compared with other disease states, more than 500,000 treatment records were reviewed examining morbidity and mortality attributable to infectious pneumonia.² An average mortality/morbidity ratio of 3.79% was observed for cattle diagnosed with infectious pneumonia. Alternatively, when examining records of diseases attributable to bloat and acidosis, a different observation was made. For disease attributed to bloat and acidosis, an average mortality/morbidity ratio of 158.7% was observed. Clearly, focusing on prevention of digestive-related diseases is paramount to reducing overall mortality prevalence.

RATION TRANSITIONS

Digestive disorders such as acidosis and bloat are interrelated and are complex disease states. Before shipment to feed yards, most cattle are on a forage-based growing program. In a typical grazing scenario, intake is regulated predominantly by physical fill; however, on a high-concentrate diet, chemostatic regulation becomes the primary method of modulating intake.⁶ Consequently, after arrival into a feed yard, cattle are normally transitioned slowly over a period of 3 or more weeks, starting with a diet of 45% to 55% concentrate and moving to an 85% to 95% concentrate diet in order for both the animal and the rumen microbial population to have ample time to adapt to diets containing readily fermentable carbohydrates.⁵⁴ Cattle that are rapidly adapted to high-concentrate diets have more variable ruminal pH response, lower intakes, and increased incidence of acidosis.⁵⁵–⁵⁷ If cattle are adjusted to diets up to 90% concentrate in less than 14 days, acidosis and poor performance can result.⁵⁴ In addition to time, managing energy intake level can be important for proper adaptation of cattle to high-concentrate diets, and many studies have shown that providing ad libitum intake during days 5 to 14 of the period of transition to high-concentrate diets usually results in dramatic reduction in intake.⁵⁴,⁵⁸
Consequently, a properly designed adaptation program for managing dietary changes and intake levels is an important aspect of transitioning cattle to diets containing high levels of readily fermentable carbohydrates.

**BUNK MANAGEMENT**

Although cattle are fed and managed as groups with multiple animals in a pen, large variation in intakes and rumen environments exists within a pen of cattle on any given day. Consequently, bunk management entails managing the bell curve of individuals within a pen of cattle by assessing cattle behavior, time at which all feed distributed in a bunk has been consumed, fecal consistency, and the health of the group. As a result, feed yard nutritionists tend to design feeding programs to find an optimal balance between productivity for most of the animals within the pen and trying to mitigate the risk of digestive disturbances for those cattle that are more susceptible to metabolic disorders. The capacity of animals to cope with grain and acid loads is highly variable, and on any given day animals within a pen are at different physiologic stages. Animals that are more acid tolerant and that have the capability to adapt more quickly to dietary and ruminal changes likely consume more feed and are more productive.

Many feed yards use a slick-bunk (or clean-bunk) feeding program in which the daily intake assignment for a pen is determined based on a bunk-scoring methodology that factors in assessments of cattle behavior, the amount of feed remaining in a bunk on a given day immediately before feeding, or the time at which cattle have consumed all the feed that was delivered to them on a given day. The goal of a slick-bunk feeding program is to maximize average intake over the feeding period while also minimizing the daily wastage of feed that can occur in an ad libitum feeding system. In a slick-bunk program, the feed yard and nutritionist strive to have most of the bunks on a feed yard void of feed immediately before the delivery of the subsequent day’s feed allotment.

The challenges to managing a slick-bunk feeding program result from the daily variation that exists in the rumen environment, cattle behavior, pen conditions, weather changes, logistical hurdles that exist from milling and delivering feed each day, and ingredient and dietary composition. Consequently, alterations in any of these factors can result in a cascade of physiologic changes in the rumen that may predispose animals to digestive issues such as acidosis and bloat. Because most feed yards stock cattle in pens to provide 22 to 30 cm (9–12 inches) per animal, not all cattle can fit at the bunk at any one time. Therefore, animals must spread their meals out throughout the day. In a feed yard setting, cattle tend to eat 8 to 12 meals per day, but there is large animal-to-animal variation as well as day-to-day variation in meal frequency and size. Consequently, if there is a dramatic change in the proportion of animals that desire to consume feed at a given time, then the rate and quantity of feed consumed can increase dramatically, resulting in rapid changes in the rumen microbial and pH environments. These engorgement and binge-eating events can be triggered by behavioral changes associated with weather and barometric pressure patterns or with variation in the time at which feed is delivered caused by logistical challenges. Therefore, social dominance structure and competition can be a factor in meal size and frequency and thereby affect the potential for digestive disorders.

The assignment of the pen’s daily feed amount can have bearing on cattle behavior and meal patterns. Many feed yards use a methodical and objective feed-calling system to apply an intake assignment to a pen based on visual assessment of the bunks throughout the time period between when cattle are fed for the last time on one day and for the first time on the subsequent day; the objective of these bunk assessments
is to determine when cattle completed eating all the feed delivered to their pen. Other programs are more subjective and rely on assessments of cattle behavior and of the proportion of animals in each pen that come to the bunk immediately after feed is delivered to the pen. In either case, if the intake assignment is drastically out of sync with the wants of the cattle, digestive disturbances can result. Nutritional programs are made even more complex with differences in cattle breeds, quality, age, and background; time of year; weather patterns; and changes in ingredient sources, moistures, and nutrient composition. If possible, the cattle populations that are more susceptible to bloat should be fed first in a sequence. Examples of these higher-risk populations may include Holsteins, cattle with more relative days on feed, and those on a beta-agonist. In order to minimize digestive upsets, a bunk management and nutritional program must strive for consistency in all aspects of intake assignment, ingredient quality, feed manufacturing, and feed delivery.

GRAIN TYPE AND PROCESSING

The grain type and degree of processing can also influence the rate and extent of digestion and hence the rumen environment and predisposition to digestive upsets. Grains vary in average starch content and are ranked in decreasing order as corn and sorghum (71%–76%), wheat (62%–65%), barley (57%–59%), and oats (44%).

Each grain type also has unique features related to the protein matrix that surrounds the starch; consequently, the rate and extent of ruminal degradation depend on the structure and type of the protein-starch matrix and the ability of rumen microbes to break down the starch within this matrix. In addition, several grain processing methods exist that can aid in this process. For example, the grain can be ground or dry-rolled, resulting in a smaller particle size and more surface area for microbes and enzymes to attack the starch. Grain can also be fermented into products such as high-moisture corn; this process breaks the pericarp, reduces particle size, and solubilizes the protein matrix that encompasses the starch molecules within the endosperm. Another common method of grain processing, steam flaking, entails gelatinizing the starch via application of steam and pressure. The total quantity and rate at which starch molecules are converted to ruminal short-chain fatty acids (VFAs), lactate, and gas are determined by the interaction of starch content, the grain processing method, and degree of processing. Taken altogether, these factors along with dietary inclusion levels of grain, roughage, and other ingredients can determine the risk to digestive upset. Therefore, it is difficult to assign the order of risk to grain type and processing method; however, because of their high starch content and rapid rate of ruminal fermentation, wheat and high-moisture corn can be feedstuffs that can elicit a rapid change in the rumen environment and a predisposition to acidosis or bloat in cattle. Similarly, although less ruminal fermentation occurs with steam-flaked corn than with wheat and high-moisture corn, a rapid fermentation rate can occur with steam-flaked corn that is processed to a higher degree. Total ruminal organic acid production is less with grains containing less starch and that are processed to a lesser degree; this results in a shift of starch digestion to the abomasum and small and large intestine for products like dry-rolled corn. However, dry-rolling of corn results in lower animal productivity and efficiency than products such as steam-flaked and high-moisture corn. For example, recently it was shown that starches from whole, dry-rolled, high-moisture, and steam-flaked corn have ruminal disappearance rates of 75%, 70%, 91%, and 85%, respectively, and total tract disappearance of starch was 85%, 91%, 99%, and 99% for whole, dry-rolled, high-moisture, and steam-flaked corn, respectively. Consequently, a balance is sought between animal
productivity and ruminal health; a slow rate of fermentation is better for prevention of acidosis, but a faster rate of degradation is better for energetic efficiency. Assessments of degree of processing of grains include visual appraisal, particle size distribution, density, protein solubility, gas production, refractometry, enzymatic conversion of starch to glucose, and fecal starch content. For dry-rolled grains, the primary methods of quality assessment are visual appraisal and particle size distribution. Fermented products such as high-moisture corn are typically appraised for particle size distribution and protein solubility. The predominant methods for assessing the quality of steam-flaked corn are on-site bulk density and laboratory enzymatic starch availability, and most nutritionists target a starch availability of 52% to 71%. Starch availability can be affected by moisture content and age of the grain, retention time in the steam chest, quantity of steam applied, roll settings, roll corrugation and wear, and storage of the grain after processing. As mentioned previously, as particle size decreases, more surface area is exposed to microbial enzymes; as a result, particle size of grain is negatively correlated to rate of digestion and viscosity or rumen contents. Diets containing finely ground grain have also been associated with reduced salivation, increased gas production, and increased occurrence of bloat. Grain type, variety, and degree of processing are important considerations for metabolic maladies such as bloat and acidosis and must be managed accordingly.

DIETARY FIBER

Although most feed yard diets are primarily composed of grain, numerous aspects of dietary forage play a critical role in ruminal and animal health and in minimizing risk for digestive upset. Roughage sources used in most feed yard diets have different physical and chemical profiles, which makes determining roughage value and equivalency difficult. Numerous attempts to assess roughage quality have been made, but the most commonly used system of categorizing roughage components, the neutral detergent fiber (NDF) method, was devised by Van Soest, in which forages are divided into a readily digestible fraction and an incompletely digestible fraction. Most feed yard nutritionists use NDF or acid detergent fiber (ADF) composition of forages for dietary formulation and roughage equivalency purposes. Before the NDF system, crude fiber content was commonly used; however, crude fiber underestimates the plant cell contents. The NDF fraction is considered to be the incompletely digestible fraction of the feed and contains cellulose, hemicellulose, and lignin, whereas the ADF fraction contains cellulose and lignin. Dairy nutritionists further defined effective NDF (eNDF) on the ability of a feed to replace roughage in a diet so that the percentage of fat in milk produced by cows eating the ration is maintained. The eNDF is based on particle size as well as adjustments for numerous other subjective factors; as a result, the eNDF values for feedstuffs is arbitrary. Physically effective NDF (peNDF) is related to the physical characteristics of fiber, such as particle size, that stimulates chewing activity and establishes the biphasic stratification of ruminal contents with a pool of liquid and small particles sitting below a floating mat of large particles. In the peNDF system of roughage comparison, long-grass hay is used as the reference feed and the peNDF of other forages are expressed as percentages (known as the physically effective factor) relative to long-grass hay, which is multiplied by the NDF content of the roughage. In high-roughage diets of dairy cows, particle size and peNDF have been positively correlated to increased chewing time, salivary output, and ruminal pH. Although feedlot cattle chew and salivate less than cattle on increased forage diets, mixed results have been observed in correlating particle length of roughages and ruminal pH in feedlot cattle. Limitations to the use of peNDF for dietary...
formulation also include reliance on book values for the physically effective factor, and this factor was generated from limited research data. In addition, peNDF does not account for ruminal degradation of the roughage and may not be a good predictor of rumen pH. Consequently, use of peNDF for dietary formulation purposes has not been widely adopted by feed yard nutritionists. Despite the variable results associated with peNDF, most nutritionists strive for longer chop lengths on hay (75–125 mm [3–5 inches]) and silage (13–19 mm [0.5–0.75 inches]); however, longer chop lengths on corn silage result in more whole kernels and increased variation in particle size unless it is kernel processed.

In terms of dietary formulation, both source and concentration of roughage affect intakes of feedlot cattle. In addition, a recent review and analysis of published data revealed that dietary NDF and eNDF supplied by roughage account for 92% and 93%, respectively, of intake responses observed in feed yard cattle, whereas dietary dry matter inclusion of roughages only accounted for 70% of the intake variation associated with roughage source and level. Many feed yard nutritionists formulate diets based on the NDF solely supplied by the dietary roughage sources (ie, forage NDF or roughage NDF). Forage NDF has been correlated to ruminal pH, which may partially explain the relationship observed between forage NDF and intake. Clinicians must be cognizant of the extreme variation that can exist in NDF or ADF content of feeds caused by roughage source, variety, maturity, and growing and harvest conditions. In addition, the fiber content of a single roughage can vary between sources (ie, farmer to farmer) and then be combined into 1 roughage supply pile or pit. Consequently, monitoring and adjusting for changing fiber content of feeds on a daily basis is extremely challenging; as a result, nutritionists tend to formulate for the average and assess and adjust for fiber changes over time. Because of the low inclusion of roughage in most feedlot diets, maintaining a minimal level of roughage in order to maintain a healthy and sustainable rumen environment is very important. Because diets are manufactured on an as-fed basis, extreme changes in moisture content of roughages caused by weather events or suppliers can have substantial impacts on the fiber composition of the diet. For example, if a roughage becomes extremely wet, the fiber content of the diet becomes reduced because of dilution with water if diets are not adjusted for moisture content of those ingredients. Therefore, monitoring for swings in moisture content of roughages is a key action that feed yards can do to ensure that the roughage requirements of cattle are met and to avoid digestive disturbances. Similarly, preceding and during storm events, cattle intakes can change dramatically; moreover, cattle intakes often increase in anticipation of a weather front. Consequently, ensuring that cattle have ample feed supplied to them as well as sufficient roughage is important. Most feed yards use so-called storm diets that contain higher inclusions of roughage for this purpose. Cattle must then be transitioned slowly off these diets and back to the regular diets.

In recent years, with the increased production of ethanol and other corn-derived byproducts for human consumption and use, the abundance of corn byproducts for cattle feed has increased, and wet corn gluten feed and corn distillers’ grains have become more common in feedlot diets. Because of the reduction in total dietary starch associated with the use of these byproducts in place of cereal grains, it has been hypothesized that these corn byproducts may thereby reduce the prevalence of acidosis in feedlot cattle. Some studies have shown that use of wet corn gluten feed increases ruminal pH or reduces variation in ruminal pH, but less conclusive results exist with the inclusion of distillers’ grains. Consequently, these byproducts may have positive effects on rumen environment but should not be used as a replacement for roughage or for mitigation of digestive maladies.
FEED ADDITIVES

Feed additives are also used as aids in productivity and ruminal health in feedlot cattle. Ionophores such as monensin have been used extensively and others, including lasalocid and laidlomycin, have been investigated and used commercially. Ionophores are a unique set of antibiotics that affect bacterial cellular membranes, thus inhibiting cellular growth and replication.82 In general, monensin selectively inhibits gram-positive bacteria because of the absence of a complex outer membrane. However, monensin is also a potent inhibitor of Butyrivibrio fibrisolvens, a gram negative bacterium.83

Researchers have shown that monensin decreases meal size and quantity and daily feed intake variation while increasing meal frequency.84,85 As a result of the changes in meals and bacterial population, monensin can increase ruminal pH and moderate changes in pH.85 The modes of action of laidlomycin and lasalocid are similar to monensin, but at currently approved feeding levels these compounds seem to have less profound effects on the ruminal levels and intake patterns.7

Regardless of the primary role of lactate in acidosis, a reduction in lactate production is beneficial in prevention of acute acidosis and improving feed efficiency. Primary lactate-producing bacteria isolated include S bovis and Lactobacillus spp, and inhibition of these bacteria has been beneficial in reducing in vitro lactate production.86 Nagaraja and colleagues11 experimentally induced lactic acidosis by ruminally infusing glucose or finely ground corn. Cattle treated with monensin had higher ruminal pH and lower concentrations of the D (−) and L (+) isomers of lactate for the glucose challenge but did not prevent lactic acidosis in the fine-ground corn challenge. Differences could have been attributable to the amount of carbohydrate infused in the rumen (fine-ground corn was greater). Burrin and Britton10 observed an increase in ruminal lactate concentrations without a concurrent decrease in pH when cattle were fed monensin. These observations could be attributed to a subacute acidic state and a low correlation between lactate concentration and ruminal pH during subacute acidosis.10 In general, monensin is effective at inhibiting lactate-producing bacteria, especially in acute acidosis, but the role of lactate inhibition in performance response observed with monensin feeding remains elusive.

Bartley and colleagues87 described the effects of monensin and lasalocid on feedlot bloat. Cattle bloated on a high-grain diet were tested with a dose of 1.32 mg/kg BW (body weight) of lasalocid or monensin with bloat being reduced by 92% and 64%, respectively. In addition, cattle dosed with 0.66 mg/kg BW lasalocid prevented bloat from developing in cattle fed high-grain diets.

Most other feed additives and ingredients that have been researched have had no or inconclusive effects. For example, the addition of sodium bicarbonate to feedlot diets has had mixed results.88,89 The use of detergents such as poloxalene have been shown to reduce pasture bloat but have not been effective in feedlot diets.33 The addition of high levels of salt to the diets of feedlot cattle has had mixed outcomes.90,91 The addition of mineral oil to feed yard diets has been shown to reduce bloat, and addition of soybean oil increased bloat, whereas tallow was neutral.92 Current research focused on rumen health and cattle productivity is centered on the use of direct-fed microbial and probiotics such as Lactobacillus acidophilus and Megasphaera elsdenii and yeast fermentation products.

SUMMARY

Cattle feeding has progressed to an efficient and sustainable production system that converts available feedstuffs into beef products that satisfy consumers’ needs.
Prevention of digestive disorders such as ruminal acidosis and bloat is achievable through a whole-systems approach. Dietary adaptation to high-concentrate diets, bunk management, grain source and degree of processing, roughage source and level, and feed additives can all affect productivity, rumen health, and digestive disturbances in feedlot cattle. Although prevention is a cornerstone, treatment and management of animals that are affected should be thorough and focus on the welfare of the animals. Numerous research opportunities exist in prevention and treatment of digestive disorders, especially as feeding programs and management systems change and new technologies become available.

REFERENCES


