Effect of bunk management on feeding behavior, ruminal acidosis and performance of feedlot cattle: A review

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ABSTRACT: Nutritionists and feedlot managers commonly attribute metabolic digestive disturbances such as subclinical acidosis to large daily shifts in feeding behavior and erratic feed intake by cattle. This perception is based on the fact that following a period of feed deprivation, free choice access to a high-concentrate diet can result in acidosis. Whether daily variability in voluntary intake of a high-grain diet by full-fed cattle compromises health or alters maintenance of ruminal pH at levels high enough for optimal ruminal function (i.e., pH <5.8) is less clear. Periodic abundance of available starch allows amylolytic bacteria (e.g., *Ruminobacter amylophilus*, *Streptococcus bovis*, *Lactobacillus* spp.) to proliferate and produce excessive quantities of fermentation acids. Presumably heightened volatile fatty acid production stimulates satiety receptors in cattle, which in turn results in the commonly observed "off-feed" or low intake syndrome. Despite this well-accepted relationship, comparatively few studies have actually demonstrated that voluntary variability in ad libitum feed intake impairs growth performance of cattle. Ruminal pH profiles differ substantially among cattle, even among those fed identical diets in equal amounts at the same time. It seems, therefore that factors other than meal size, and feeding regimen determine an animal's susceptibility to subclinical acidosis and ultimately influence growth performance. Feedlot management practices developed to regulate feeding behavior, and decrease variations in feed intake by penned cattle include programmed feeding, multiple feed deliveries per day, and consistent timing of feed delivery. However, the efficacy of these practices in reducing animal-to-animal variability is assessed largely on the basis of intake per pen, with little or no appreciation for the variation in feed intake among individuals. Further characterization of this variability in feeding behaviors among penmates could provide the foundation for further refinement of present feeding practices.

Key Words: Acidosis, Cattle, Feed Intake, Feeding Behavior, Management

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Introduction

The relationship between feeding management, feed intake, animal performance, and the incidence of metabolic disorders such as ruminal acidosis remains unclear. Nutritionists and feedlot managers attribute subclinical acidosis and reduced performance to erratic feeding behavior and intake by cattle, which is believed to result in losses of as much as $15 to 20 per animal in lost efficiency. Although several studies have concluded that large variations in intake by cattle fed high-concentrate diets may cause digestive disturbances (Fulton et al., 1979; Britton and Stock, 1987) few studies have confirmed that variability in ad libitum feed intake reduces growth performance of cattle.

The goal of bunk management practices such as programmed feeding, multiple feed deliveries per day, and consistent timing of feed delivery is to reduce variability in intake. The effectiveness of these practices is based on pen average intakes even though there can be significant differences in the ruminal profiles, and feeding behavior among individuals within a pen. The ability to monitor the feeding patterns, and ruminal profiles of individual feedlot cattle will aid in identifying factors, other than feeding regime and meal size, that increase an animal's susceptibility to subclinical acidosis, and reduce performance. This paper will review past work as well as introduce new approaches including radio frequency technologies to gain a better understanding of the complex relationship between feed intake, feeding behavior, acidosis, and performance.

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Effect of Intake on Rumen Ecology

The impact of intake on ruminal ecology probably is most profound during the transition from a forage-based to a grain-based diet. During this transition, fibrolytic bacteria become less prevalent, and amylolytic bacteria increase (Goad et al., 1998; Tajima et al., 2001). Once transition is complete, the size of various carbohydrate-utilizing microbial populations is remarkably constant in ruminants fed forage or concentrate diets at moderate levels of intake (Leedle et al., 1982). For example, Mackie and Gilchrist (1978) found that numbers of cellulolytic bacteria in the rumen remained unchanged once adaptation from roughage to a 70% corn diet was complete. Similarly, Klieve et al. (2002; unpublished data) found that ruminal *Streptococcus bovis* populations remained relatively constant after steers were adapted from a forage-to a concentrate-based diet. Numbers of cellulolytic bacteria typically decrease, and amylolytic bacteria increase when intake of nonstructural carbohydrates results in a ruminal pH of less than 5.5 (Slyter et al., 1970; Allison et al., 1975).

Earlier reports indicated that ruminal protozoa were virtually absent (Eadie et al., 1970; Lyle et al., 1981) or dramatically reduced (Slyter et al., 1970; Vance et al., 1972) in cattle fed a high-grain diet. However, researchers have more recently shown that whereas protozoal diversity is reduced, numbers of some protozoal genera (e.g., *Entodinium* spp.) remain high in cattle fed wheat- (Kreikemeier et al., 1990), barley- (Hristov et al., 2001) corn-, and sorghum-based diets (Towne et al., 1990a, 1990b; Franzolin and Dehority, 1996). *Entodinium* spp. may reduce the risk of subclinical, and clinical acidosis through their ability to utilize lactate (Newbold et al., 1987) and to moderate the rate of starch digestion by ingestion of starch granules (Williams and Coleman, 1992).

The development of subclinical, and clinical acidosis in feedlot cattle involves a complex interaction among intake, diet composition, ruminal microorganisms, and the animal (Figure 1). Establishment of a stable microflora during transition from a forage to a concentrate diet is not immediate. Introduction of highly fermentable starch into the diet increases the availability of free glucose, and stimulates the growth of most ruminal bacteria, thereby increasing production of VFA, and decreasing ruminal pH (Owens et al., 1998). Competition for substrate normally moderates the growth rate of lactic acid-producing bacteria (e.g., *S. bovis*, *Lactobacillus* spp.), and the number of these microorganisms seldom exceeds 10^7 cells / mL of ruminal fluid. Accumulation of lactic acid is curtailed by an increase in the number of lactic acid-utilizing bacteria (i.e., *Selenomonas* spp, *Anaerovibrio* spp., *Megasphaera elsdenii* and *Propionibacterium* spp.), and protozoa (i.e., *Entodinium* spp.) in the rumen. Thus, a balance between production and utilization of lactic acid is maintained and concentrations of lactic acid in ruminal fluid from animals perceived to have subclinical acidosis seldom exceeds 10 m*M* (Harmon et al., 1985; Burrin and Britton, 1986; Goad et al., 1998; Hristov et al., 2001; Ghorbani et al., 2002). However, in a small subset of cattle the microbial population may become unstable, resulting in clinical acidosis. In these individuals, competition for substrates does not restrict growth of *S. bovis*, and with a doubling time of 20 min, this bacterium may soon reach populations of 10^9 cells / mL of ruminal fluid (Allison et al., 1975; Klieve et al., 2002, unpublished data). The resulting abundance of glycolytic intermediates (e.g., pyruvate, fructose-1,6-diphosphate) promotes a shift in the metabolism of *S. bovis* from production of acetate, and formate to production of lactate (Russell and Hino, 1985). Lactic acid ($pK_a = 3.1$) is over 10 times as strong an acid as the VFA normally produced in the rumen (average $pK_a = 4.8$), thus production of this alternative metabolite exacerbates the decline in pH. Cellulolytic bacteria, and protozoa are inhibited at pH below 6.0 (Stewart, 1977; Williams and Coleman, 1992), and as the pH decreases below 5.2 in select individuals, the normally diverse microflora of the rumen is largely replaced by acid-tolerant *S. bovis* and *Lactobacillus* spp.. With a continuous drop in pH, growth of *S. bovis* is inhibited (Therion et al., 1982). At pH below 4.7, a virtual monoculture of acid-tolerant Lactobacilli develops (Allison et al., 1975). Identification of the factors that contribute to the susceptibility of these few individuals to subclinical or clinical acidosis may provide the key to developing feeding practices that further reduce the risk of acidosis.

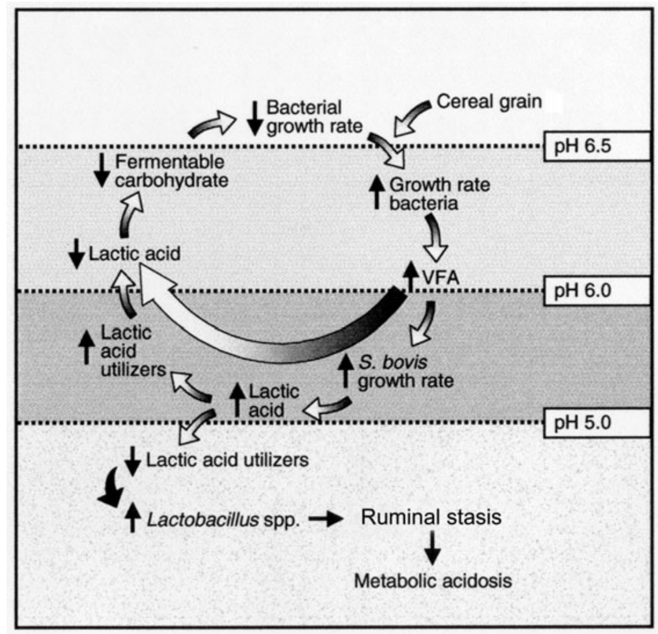

Figure 1. Metabolic consequences of feed intake in finishing feedlot cattle on ruminal pH and microbial populations of the rumen. Note that in the majority of animals ruminal pH decreases below 6.0 without a significant increase in ruminal lactic acid concentration or in numbers of *Streptococcus bovis* in the rumen.

Subclinical Ruminal Acidosis

In North America, diets consumed by feedlot cattle typically contain mostly grain, and provide little fiber from forages. These high quality diets are rapidly digested in the rumen, which leads to high concentrations of VFA in ruminal fluid (> 100 m*M*), and relatively low ruminal pH (Beauchemin et al., 2001).

Clinical acidosis is often precipitated by an abrupt dietary change that destabilizes the ruminal microbial populations. Numerous in vitro, in sacco, and in vivo studies have shown that the ability of the major cellulolytic bacteria to degrade cellulose is negatively affected when pH is below 6.0 (Mould et al., 1983, 1984; Russell and Wilson, 1996). Various pH threshold values have been set arbitrarily to define subclinical acidosis: 5.5 (Hibbard et al., 1995; Reinhardt et al., 1997), 5.6 (Cooper et al., 1999), 5.8 (Beauchemin et al., 2001; Ghorbani et al., 2002; Koenig et al., 2002), and 6.0 (Bauer et al., 1995; Krehbiel et al., 1995). However, mean pH may not be a good indicator of this condition. In many cases, mean pH is calculated by averaging several spot samples taken before, and after feeding. This approach can be misleading because it does not reflect the diurnal fluctuations in pH. For example, cattle with a mean ruminal pH of 6.0 can experience long periods each day during which the pH is below 5.5. Recently, indwelling electrodes have been used to measure diurnal fluctuations in ruminal pH over extended periods of time (Dado and Allen, 1993; Krause et al., 1998; Cooper et al., 1999). For the purposes of this discussion, subclinical acidosis will be considered to exist when ruminal pH falls below 5.8 for more than 12 h /d.

Ruminal pH Profiles of Feedlot Cattle

Mean ruminal pH of feedlot cattle fed high-grain diets is usually between 5.6 and 6.2. The lower values are typically observed when more fermentable diets are fed (Krause et al., 1998; Cooper et al., 1999; Beauchemin et al., 2001; Ghorbani et al., 2001; Koenig et al., 2002). Under typical commercial feeding conditions, ruminal pH varies significantly over the course of the day. Most feedlot cattle experience low ruminal pH at least a portion of each day. The pH is highest just before the morning feeding, as cattle tend to ruminate at night, and eat during the day. After feeding, the pH drops as fermentation of dietary carbohydrate commences. Nadir or lowest pH typically occurs 11 to 13 h after feeding (Figure 2). Mean nadir pH in feedlot cattle usually varies from 5.0 to 6.5 (Bauer et al., 1995; Goad et al., 1998; Beauchemin et al., 2001, Koenig et al., 2002) and is influenced primarily by the rate of ruminal feed digestion. Thus, factors influencing this rate, such as forage-to-concentrate ratio, source of grain, and extent of grain processing as well as size, number, and frequency of meals can also have large effects on nadir pH.

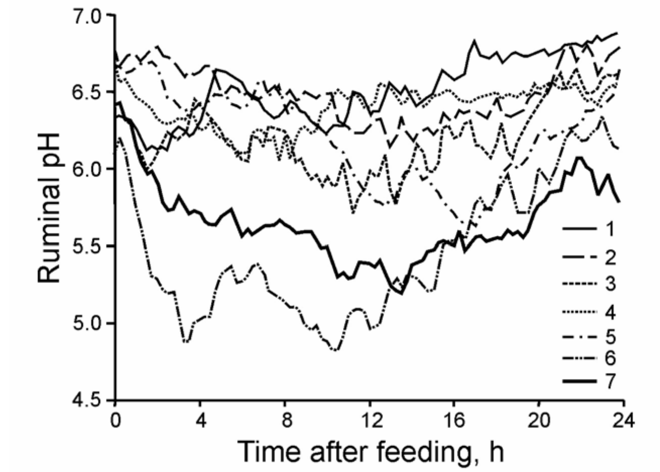

Figure 2. Changes in ruminal pH following feeding of a high-grain finishing diet (115% of ad libitum intake, 0900 h daily) to feedlot steers fitted with indwelling ruminal pH electrodes. Animals were individually penned and each line represents an individual steer. Values shown are 15-min averages of values recorded at 60-s intervals. Variation in ruminal pH of individual steers was not correlated with DMI (Krause et al., 1998).

Adaptive Responses

Individual cattle vary in their ability to cope with the metabolic challenges posed by extensive and rapid fermentation of high-grain diets. It is well recognized that feedlot cattle require an adaptation period of 10 to 14 d to make the transition from high-forage to high-grain diets. In fact, clinical and subclinical acidosis can be induced experimentally by eliminating this adaptation phase, and abruptly changing diet composition (Goad et al., 1998; Coe et al., 1999). Moreover, cattle can vary markedly in their ability to cope with the dietary factors that predispose them to acidosis after adaptation to high-grain diets (Dougherty et al., 1975; Brown et al., 2000). Thus, it is not surprising that under typical commercial feedlot conditions patterns of ruminal pH vary tremendously among animals receiving the same diet (Figure 2).

The reasons that some animals experience subclinical acidosis while others are metabolically capable of coping with this challenge are not clear. Differences among cattle may be related in part to the stability of microbial populations as discussed previously. Additionally, the ability or inability to maintain high ruminal pH may also be related to their feed preference, and selectivity at the bunk or the rate at which particular animals consume feed. Cattle that consume grain selectively may consume insufficient fiber for stimulating adequate chewing and salivary secretion to balance the acids produced during fermentation. Intake of forage fiber is known to stimulate rumination activity during which time salivary secretion increases (Beauchemin, 1991). Cattle consuming high-grain diets secrete only

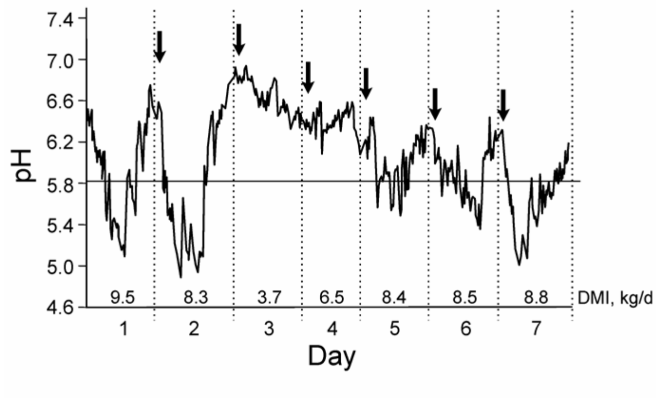

Figure 3. Ruminal pH and DMI of a single steer given continual access to a barley-based finishing (fully adapted) diet (14.6% CP) over a 7-d period. Arrows indicate feed delivery times.

60 to 70% as much saliva as cattle fed similar amounts of forage, and saliva secretion among animals receiving the same diet can vary by as much as 25% (Bailey, 1961). However, the relationship between the variation in salivary output by individual animals, and the incidence of subclinical acidosis has not been established. Subclinical acidosis can reduce feed intake, and thereby impede growth of feedlot cattle. Low ruminal pH can cause erratic intake patterns (Bauer et al., 1995; Fulton et al., 1979; Stock et al., 1995). Brown et al. (2000) observed a high correlation for feedlot cattle between feed intake and lowest daily ruminal pH on the previous day indicating that animals may adjust their subsequent intake if pH is low. Similarly, we observed that when ruminal pH is low, some animals decrease intake presumably in an attempt to limit the production of fermentation acids and restore pH conditions to a "comfortable" level (Figure 3, K. A. Beauchemin, unpublished data). Once the pH is restored, the cattle resume a high level of feed intake that leads once again to excessive production of acids, causing the cycle to repeat. This effect was monitored using an indwelling pH probe in the rumen of a feedlot steer fed a diet containing 92% barley-based concentrate (14.6% CP), on a DM basis.

Intake and Acid Utilization

Acid Absorption

Differences in the susceptibility of feedlot cattle to subclinical acidosis are not easily explained by acid absorption or metabolism. Fatty acids are readily absorbed from the rumen, (Bergman, 1990; Sharp et al., 1982) at rates enhanced by lower pH (Masson and Philipson, 1951) despite the fact that only a low proportion of VFA exist in the undissociated form at physiological pH ranges. Assuming an average pK_a of 4.8 for VFA, the proportions of VFA that are in the free acid form are approximately 0.6%, 6%, and 39% at ruminal pH of 7, 6, and 5, respectively (Mathews and van Holde, 1990). Hydration of CO_2 at the rumen wall forms HCO_3^- and supplies a proton for converting dissociated VFA to the more readily absorbed free acid form (Bugaut, 1987).

Even if VFA absorption in the rumen is reduced due to parakeratosis or other tissue damage, the omasum, abomasum, and large intestine efficiently absorb VFA (Stevens, 1973a,b; Stevens et al., 1980). The low pH of the abomasum likely ensures that all ruminal VFA is absorbed prior to the duodenum (Peters et al., 1990).

Acid Metabolism

The gut plus its contents uses a disproportionate amount of energy (approximately 25% of total oxygen consumption) for the size of the tissue (approximately 6% of BW), with essentially all of this energy being derived from VFA (Britton and Krehbiel, 1993). Absorption rates for the primary ruminal VFA are butyrate > propionate > acetate. However, quantities appearing in venous effluent are in the reverse order, due to preferential metabolism of butyrate, and propionate (Bergman, 1990).

Fatty acids are utilized through intermediary metabolism following formation of the respective CoA metabolites. Differences between species may exist in the rate of formation of these metabolites in specific tissues. For example, propionyl-CoA synthetase activity is approximately equal in ruminal epithelium and liver in sheep, whereas it is three to four times higher in liver than epithelium tissue of cattle (Elliot, 1980).

The majority of propionate and butyrate entering portal blood is metabolized in the liver. Consequently, acetate accounts for over 90% of the VFA in arterial blood (Bergman, 1990). Providing that the required metabolic cofactors (e.g., biotin, vitamin B_{12}) are available, it is unlikely that VFA metabolism accounts for the variability in susceptibility of feedlot cattle to subclinical acidosis.

Intake and Feeding Behavior

Animal scientists traditionally have focused largely on the nutritional and physiological aspects of metabolic disorders and performance. As a result, a plethora of research studies have evaluated diet formulations, feed processing techniques, and feeding management aimed at improving intake, and performance, and reducing the occurrence of metabolic disorders. However, factors other than these may determine an animal's susceptibility to subclinical acidosis and consequently its growth performance. Feeding behavior, dominance, temperament, and motivation may play as large a part in subclinical acidosis as the type, and amount of feed an animal ingests (Zinn, 1994; Voisenet et al., 1997;

Owens et al., 1998; Grant and Albright, 2001). Cattle fed commercially typically are housed in large groups where social status and learning may affect eating patterns (Galyean and Eng, 1998).

Recent studies indicate that intake patterns differ markedly among individuals within a pen (Gibb et al., 1998; Hickman et al., 2002; Schwartzkopf-Genswein et al., 2002). Large pen trials comparing individual feeding patterns with ruminal pH and performance are nonexistent because continuous monitoring of ruminal pH on individual animals is difficult at best. The development of new technologies that overcome such data acquisition problems will aid in unraveling the complex relationship between intake, metabolic disorders, and performance.

Feeding Management

One goal of feeding management has been to moderate feeding behavior, and reduce daily variation in intake among penned feedlot cattle (Bauer et al., 1995; Gibb et al., 1998; Galyean, 2001). Feeding regimes may act in harmony with feeding behavior or they may be disruptive. For example, digestive upsets may be minimized due to a more uniform intake of fermentable carbohydrates if the feeding regime leads to smaller, more frequent eating episodes. In contrast, intermittent binge feeding is believed to contribute to metabolic disturbances (Pritchard and Knutsen, 1995). At this time, however, the extent to which feeding can be manipulated to maximize DMI, and minimize digestive upsets in group-fed cattle is largely unknown.

Ad libitum vs Restricted Feeding.

Feedlot cattle usually are given continual access to feed in an attempt to maximize feed intake. This strategy is known as ad libitum or free-choice feeding. Bunk management strategies in this scenario focus primarily on maintaining bunk hygiene by adjusting the amount of feed provided so that residual feed (weighbacks) does not exceed a small percentage of what was delivered (Galyean, 1999; Schwartzkopf-Genswein and Gibb, 2000).

Restricted feed delivery limits intake relative to actual or anticipated ad libitum intake (Galyean, 1999). The goal of restricted feed delivery is to improve performance by reducing digestive problems from overconsumption of feed. Generally, feed is restricted by 0.5 or 1 kg per meal. Whereas ad libitum feeding attempts to maximize intake on a daily basis, restricted feeding strives to maximize mean intake over the course of the feeding period (Galyean, 1999). However, restricting feed access may cause subclinical acidosis and, an overall reduction in mean intake. This is because restricted feeding typically results in animals becoming meal eaters (consuming a few large meals); although the variation in their total daily feed intake is reduced (Zinn, 1995), variability in the ruminal environment within a day may be increased. Studies investigating the effects of bunk management have produced conflicting results. Fanning et al. (1999) reported that as a consequence of changes in eating patterns, cattle fed on a restricted protocol exhibited lower, and more variable ruminal pH than those provided ad libitum access to feed. Larger meals and a faster rate of eating resulted in a greater pH decline in the restrictively-fed cattle. In contrast, Gibb et al. (1998) reported that individual cattle exhibited less day-to-day variation in time spent at the bunk when they were limit-fed (95% of ad libitum intake) than when they were on full feed.

The assumption that positive animal responses to bunk management (if present) are a direct result of reduced acidosis is unsubstantiated. The findings of Fanning et al. (1999) contradict these assumptions, but the practice of slickbunk management to improve performance is not necessarily discredited. Increased eating rates and less frequent meals are commonly observed among cattle given limited access to feed (Gibb et al., 1998; Prawl et al., 1998; Fanning et al., 1999; Schwartzkopf-Genswein et al., 2002). Increased eating rates have been associated with improved performance in sheep (Church et al., 1980) and with increased intake and performance by cattle (Frisch and Vercoe, 1969; Prawl et al., 1997). Streeter et al. (1999) identified an apparent negative correlation between time spent at the feed bunk and ADG, which suggests that cattle with higher growth rates likely also have higher eating rates. Similar results were found by Schwartzkopf-Genswein et al. (unpublished) for cattle receiving an 85% barley grain finishing diet. In contrast, cattle that spent the most time at the bunk had the highest ADG when the diet consisted of 60% barley silage. These data must be interpreted carefully, however, because the relationships between average time duration at the bunk, attendance, and intake are poor (Gibb et al., 1998; Schwartzkopf-Genswein et al., 2002).

Variation in Feed Intake

It is commonly assumed that fluctuations in intake can cause acidosis and reduce mean DMI (Britton and Stock, 1987). This belief, held by many cattle feeders, is supported by a study of Galyean et al. (1992) in which deliberate 10% fluctuations in feed delivery to cattle reduced gain by 6% and feed efficiency by 7%, compared to cattle receiving feed according to a constant programmed feeding schedule based on BW. In that study, impaired performance was attributed to subclinical acidosis arising from intake variation, even though ruminal pH was not measured. This theory remains prevalent despite a mounting body of research that has contradicted these findings (Zinn, 1994; Stock et al. 1995; Cooper et al., 1998a; Owens et al., 1998; Soto-Navarro et al., 2000; Hickman et al., 2002). Monitoring ruminal pH in a metabolism trial, and animal performance in a finishing trial that included deliberate fluctuations in intake, Cooper et al. (1998b) observed that ruminal pH was lower in limit-fed cattle with day-to-day intakes varying by 1.4 kg, than in those receiving constant amounts of feed. Ruminal pH did not differ among cattle consuming a fluctuating amount of feed and there were also no differences in pH among ad libitum fed cattle. During the study, an equipment malfunction delayed feeding for 4 h at which time it was observed that delayed feeding (such as could arise in a commercial lot, with equipment breakdown or inconsistent timing of feed delivery) can have a greater effect on ruminal pH than fluctuating quantities of feed. In a finishing trial by Cooper et al. (1998a), fluctuating the daily amount fed by 1.8 kg/d numerically increased intake but did not affect ADG or feed conversion. Similar results were obtained by Schwartzkopf-Genswein et al. (2002) in a finishing trial comparing cattle fed at a constant level (ad libitum intake) with cattle fed amounts of feed fluctuating by 10% above, and below ad libitum intake for three consecutive days. Constant- and fluctuating-fed animals exhibited similar intake, ADG, feed efficiency, and time spent at the bunk. However, mean ruminal pH was 0.10 units lower in fluctuating-fed compared to constant-fed animals, and remained lower for a greater portion of the day in a smaller metabolism trial in which the same feeding strategies were applied (Figure 4; Schwartzkopf-Genswein et al., 2002). This study suggested that mean ruminal pH may increase when cattle are introduced to high-grain diets, and their day-to-day intake is more likely to fluctuate after a period of adaptation; however, mean, and minimum pH became similar between feeding regimes, as did animal performance. These data imply that cattle consuming high-concentrate diets can adjust metabolically to inconsistencies in feed delivery, and intake after an adaptation period of at least 28 d.

A recent study conducted by Hickman et al. (2002) evaluated the relationship between eating patterns and performance in feedlot cattle by electronically tracking individual visits, and feed consumption. Daily variation in intake (defined as difference in total amount of feed consumed between consecutive days) by individual animals was compared among animals grouped according to high, average or low DMI, ADG, or feed efficiency. High ADG steers (n = 9) had daily variation in intake that was on average 0.36 kg higher, consumed 2.1 kg more feed, and spent 3.7 min / d less time at the bunk than did low ADG steers (n = 13). Similarly, steers with the highest feed efficiency (feed:gain) had higher daily variation in intake (0.38 kg), and lower intake (1.1 kg) than steers with low feed efficiency. It was concluded that the best-performing (ADG and feed efficiency) cattle have the most variable feeding patterns which is contrary to industry belief. This study is valuable as it illustrates the variation in intake by individual animals that may be lost when performance, and intake parameters are assessed on a pen basis. Patterns of intake by individual cattle categorized into high or low ADG groups are presented in Figure 5. Feed intake by individuals in the low ADG group was consistently below the pen average, whereas those in the high ADG group consistently consumed more (Figure 5). The need for further investigation, and refinement of feeding practices to include the evaluation of individual feeding behavior is emphasized. Daily variation in feed intake may not impact ruminal pH as much as the rate at which feed is consumed.

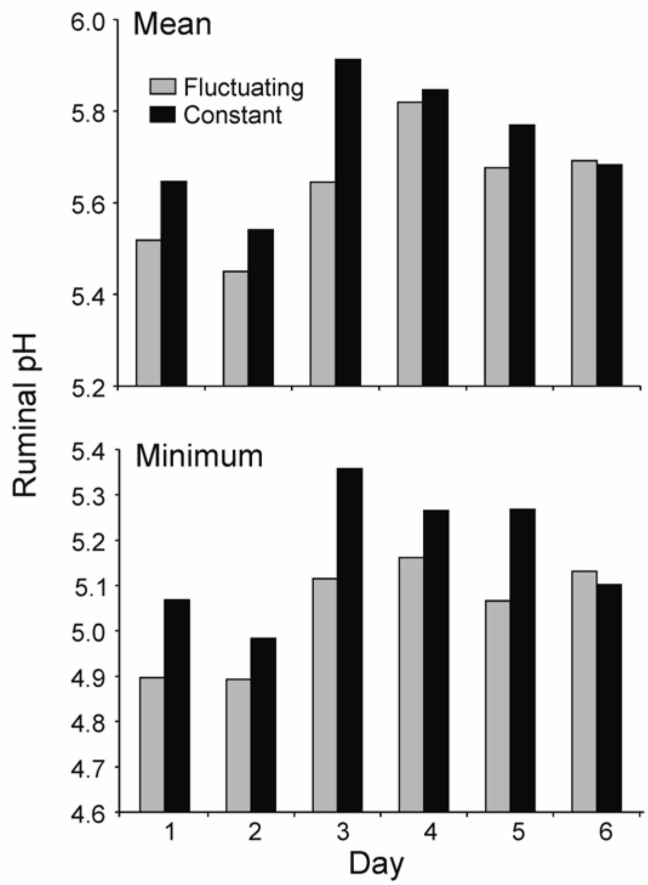

Figure 4. Mean (upper graph) and average minimum (lower graph) ruminal pH recorded in feedlot steers, (n = 6) fed a high-grain finishing diet offered once daily. Steers received feed delivered in a constant amount equal to their previously determined ad libitum intake (black bars) or at 110% of ad libitum for d 1 to 3, followed by 90% of ad libitum intake for d 4 to 6 (grey bars). Mean pH values are averages of values recorded at 15-min intervals using indwelling pH probes.

Finally, cattle may have an ability to alter or regulate their intake patterns such that variation in feed delivery has less impact than expected. Evaluation of the effects of early or late feed delivery (0800 or 2100 h) on performance, and feeding behavior of cattle revealed no changes in diurnal feeding patterns in response to feeding times (Figure 6; Schwartzkopf-Genswein et al., 2000). Even restricting feed delivery to 85% of ad libitum intake was not sufficient to change the normal diurnal feeding patterns of those cattle. This study indicates that certain behaviors are inherent, and not easily

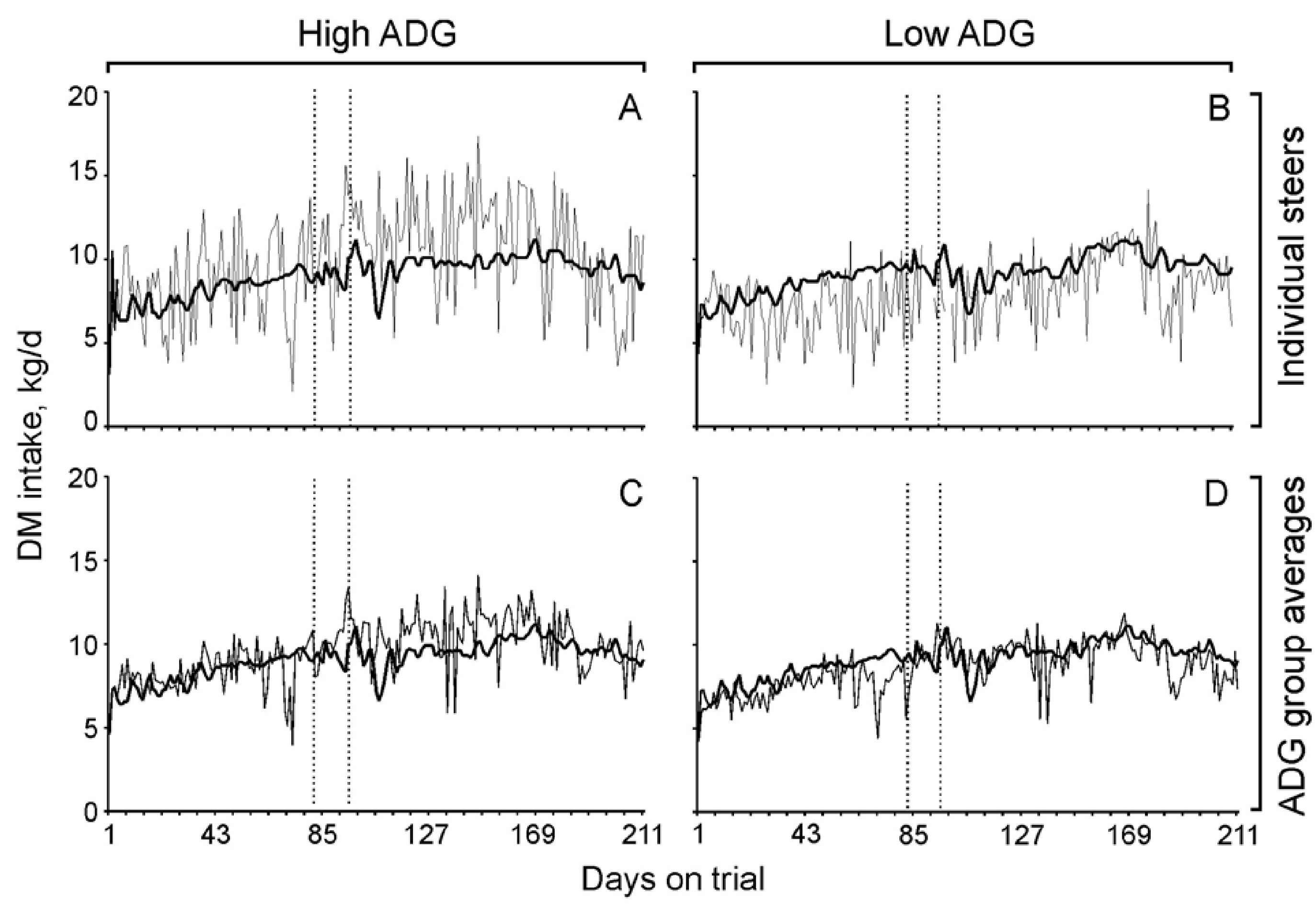

Figure 5. Daily variation in dry matter intake by feedlot steers receiving barley silage/barley grain-based diets (growing diet at 80% silage and 20 % grain; finishing diet at 20% silage and 80 % grain on an as-fed basis) ad libitum in a 211-d feeding trial during which individual intake was monitored by radio frequency transmission, and after which steers were categorized as having high, average, or low ADG (over mean + 1 SD, within mean ± 1 SD, or below mean − 1 SD). Panels A and C contain data collected on an individual steer (A;), and the entire group (n = 9) of (C) high ADG steers; panels B and D contain data collected on an individual steer (B), and the entire group (n = 13) of (D) low ADG steers. Bold lines indicate amounts of feed (kg DM/steer) delivered to each steer's pen (A, B) or mean of deliveries to all pens (C, D). Dashed vertical lines indicate the transition period (separates growing and finishing periods) where grain was gradually increased from 20% to 80% (as-fed basis). Mean (± SD) start and finish weights for steers were 311.7 ± 50.6 and 577.9 ± 53.7 kg, respectively.

altered. Thus, the tendency of individuals to adapt their feeding patterns to any change in feed delivery may also play an important role in modulating metabolic disorders.

Potential for the Genetic Improvement of Feeding Behavior

Several studies, involving both beef and dairy cattle, suggest that various measures of temperament, and other behavioral characteristics are slightly to moderately heritable (Hohenboken, 1986; Le Neindre et al., 1995). However, studies of the inheritance of feeding behavior have been limited in scope because of the difficulty in collecting sufficient data for parameter estimation. Voisenet et al. (1997) showed a favorable correlation between docility, and performance. With further study, the potential may exist to select for improvements in the behavioral aspects of feed intake. However, indirect selection may have been practiced, as Schutz and Pajor (2001) suggest, for more optimal feeding behavior as a correlated response to improved growth rate. Since intake variation does not appear to have a drastic effect on performance, selection for feed efficiency may still be the most useful criterion to employ in animal breeding programs.

Implications

The majority of pen-fed cattle can and do tolerate fluctuations in feed delivery and consumption. Recent

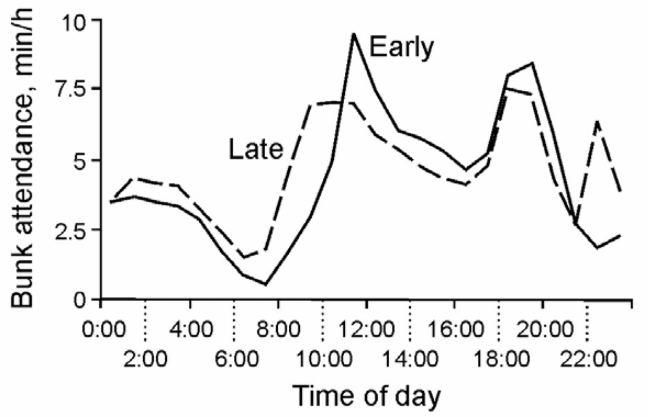

Figure 6. Effect of timing of once-daily feed delivery on bunk attendance patterns of feedlot cattle (n = 240) given 24-h, free-choice access to a barley-based diet over a 210-d period (December- July). Early: feed delivered at 0800 daily; late: feed delivered at 2100 daily. Values plotted are means of hourly totals recorded over the course of the study. Mean ADG and feed efficiency for early and late fed animals were (1.22 ± 0.10 and 1.25 ± 0.10 kg/d) and (6.25 ± 0.2 and 6.37 ± 0.2), respectively.

data have shown marked individual variability in feed intake, feeding behavior, and ruminal pH profiles. The role of management in subclinical acidosis may remain unclear if pen average data continue to be the evaluation benchmark. It is imperative to monitor individual animal feeding behavior (using technology such as radio frequency) so that the variables related to metabolic disorders can be identified. A growing body of data demonstrates that feedlot cattle on finishing diets can readily adapt (physiologically and behaviorally), such that day-to-day intake variability does not negatively affect performance; however, cattle may be less able to adapt to changes during the transition period. Future studies should include evaluations of intake variation and the incidence of subclinical acidosis during the transition period when instability in ruminal microflora and pH are highest.

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