Promising management strategies and feed additives to prevent liver abscesses and disease

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Abstract

Continued scrutiny by an ever-critical public demanding responsible animal care and judicious use of antibiotics in livestock production are the main drivers to consider alternative solutions to liver abscesses and other feedlot disease. Whether antibiotic feed use in cattle feeding contributes to resistant strains of bacteria and renders certain classes of antibiotics less effective to treat human disease is not relevant to this discussion anymore. What is not known is how long livestock producers and the industry and professionals that serve them have to develop alternatives. Challenges associated with understanding how and when liver abscesses occur contribute to this lag in developing alternative solutions. A review of various non-antibiotic feed additives is provided here. Yet, there was no non-antibiotic feed additive that was a suitable candidate to replace tylosin. Furthermore, if identified, other challenges in implementing a suitable replacement exist; namely, inclusion rate, storage requirements and shelf-life. Perhaps, dedicating greater research and education efforts towards creating a more stable rumen environment by understanding how moisture content of feeds affects dietary dry matter delivery and how human behavior affects response to bunk scores may be a faster route to solve this challenge while demonstrating care for the animals that serve us.

Key words: liver abscess, dry matter intake, management

Introduction

Optimum nutritional management of feedlot cattle is based on achieving a steady state in rumen fermentation. This is particularly true when feeding diets high in fermentable carbohydrates — most feedlot diets. Yet, factors external to nutrient content of feeds challenge even the most astute cattle feeder and their consulting professional (veterinarian and/or nutritionist) to achieve a consistent ruminal fermentation environment. These factors include variation in moisture concentration of feeds (affected by either environmental exposure, harvest conditions or both) and the response by the human eye (bunk call) to visual appraisal of feed remaining in the bunk (bunk score).

These factors, although seemingly unrelated, have the capacity to interact with each other. Consider the case of an ambitious bunk call exacerbated by a sudden change in moisture content of the feed (such as that observed following a rain event on improperly protected feed ingredients). The result of this combination on cattle adapting to the finisher diets or cattle on the finisher diet beginning to be exposed to inclement weather may have lasting impacts on intake and performance.

A book published in 1980 by the Committee to Study the Human Health Effects of Subtherapeutic Antibiotic Use in Animal Feeds of the Division of Medical Sciences of the National Research Council[9] represents one of the earliest reports by a U.S. scientific society on the subject of antibiotic use in animal feeds and antibiotic resistance in humans. A fool may determine that, because the original report on the subject was written 42 years ago, and although additional evidence likely accumulated on the subject, society will move on ignoring any association between sub-therapeutic antibiotic use in animal feed and human health. A pessimist may determine that the end of the sub-therapeutic antibiotic use in animal feed era is near because we have at least 42 years of accumulated results and societal pressure on this issue. Lastly, the optimist may regard the 42 years since publication of the committee's report as a grace period during which university, additive company and private practitioner nutritionists and veterinarians should have been able to develop alternative management strategies or non-antibiotic feed additives to prevent disease in the feedlot.

Two of the scenarios given above likely represent the reality of how society will decide to move on this subject. Recent changes brought about by voting ballots in various states should serve as a warning to the fool described in the above scenario. Even the optimist in the scenario above should recognize that we do not have another 42 years to develop alternatives to sub-therapeutic antibiotic use in animal feeds; lest they be deemed fools, also.

Information contained in this manuscript is intended to inform the reader on:

1. Effects of changes in moisture content of feed ingredients on feed deliveries
2. Focus on the human response to bunk scores as a contributor to intake variation
3. Provide a review of the most promising alternative feed additives to reduce incidence of liver abscesses or aid in prevention of respiratory disease in newly received cattle
4. Other management considerations

The baseline — current feed additives and prevailing management strategies

Feedlot management progressed extensively since the late 1980s. Cattle inventories shrank rapidly since the 1970s. The U.S. beef cowherd declined from 45.7 million head in 1974 to the current inventory of 31.1 million head. Yet, beef production remains relatively constant.[19] Improvements in productivity derived from industry-wide applications of improved cattle genetics, feeding management and health protocols along with greater reliance on higher dietary energy content supported by growth-promoting agents and antibiotic feed additives led to this increase in productivity. The U.S. beef cowherd simply shrinks owing to lower demand for beef on the hoof. This trend is likely to continue.

On the feedlot, production conditions are as varied as there are feedlot managers. Ingenuity and an innate desire to improve not just profitability but quality of life for human and beast define the better manager or owner. The capacity of a feedlot manager for disease and liver abscess prevention is likely linked to these traits.

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Feedlot managers who strive to optimize feed, feeding and pen management strategically relying on disease prevention and prompt disease treatment set themselves apart from the average. These individuals consider the importance of feed storage and inventory control to preserve feed quantity and quality. Investments in this area are compensated by lower feed loss, greater dietary quality, and more consistent performance. Beyond feed storage and inventory control, astute feedlot managers rely on technology to optimize feed ingredient loading, mixing and delivery. They understand that errors in loading amounts, mixing times, improper mixing order or time, and off-time or inexact (space or amount) deliveries lead to serious dietary composition or intake fluctuations that risk ruminal health and performance. Under these production conditions, feed additives such as ionophores, disease and liver abscess-preventing antibiotics are supportive to the process.

Throughout the years, feedlots and their consulting nutritionists and veterinarians have relied on one of three antibiotics approved for reduction of liver abscesses by the Food and Drug Administration (FDA). These antibiotics are:

- Tylosin (Tylan® and Tylovet®) for the reduction of liver abscess abscess incidence caused by Fusobacterium *necrophorum* and *Truperella pyogenes*
- Virginiamycin (V-Max®) for reduction of liver abscesses
- Bacitracin methylene disalicylate (BMD® and Pennitracin MD®) for reduction in the number of liver condemnations due to abscesses
- Oxytetracycline (Terramycin® and Pennox®) or chlortetracycline (Aureomycin® and Pennchlor®) for reduction of incidence of liver abscesses

Chlortetracycline and, to a lesser extent, oxytetracycline, are also used to treat bacterial pneumonia and the early stages of shipping fever complex, respectively.

Bunk scoring was first conceived by Dr. Robbi Pritchard at South Dakota State University in the early 1990s. The premise of this scoring system led to implementation of slick-bunk feeding. Prior to this ingenious development, cattle feeders "full-fed" cattle. This feeding method relied on always having feed left over in the bunk. This approach was predicated on the idea that, as long as feed was available, ruminal fermentation proceeded in a steady state. Improvements in feed conversion efficiency observed when feedlot managers adopted the bunk scoring system and subsequently fed in response to this score (bunk call or amount of feed called for based on the visual assessment of feed left in the bunk or bunk score) made adoption of this system nearly universal and immediate.

Bunk scoring is regularly accomplished in the morning before feeding is started. However, in some cases, feed delivery may occur immediately after bunks are scored if morning loads carrying 50% of less than the projected daily feed delivery are on the protocol. Bunk calls are then used to adjust the amount delivered once, twice or thrice daily. The most recent survey[13] of feedlot consulting nutritionists revealed that, of feedlots consultants serviced, only 8% of them delivered feed once daily while 54% and 48% of feedlots serviced, respectively, delivered feed twice and thrice daily.

Beyond the bunk, management practices vary immensely and are dictated by geographic location, weather, topography, feedlot design and local feedlot manure regulations. Concrete feed site aprons are a norm unless the pen is in a confinement feedlot on slats; yet, apron width is not normalized across feedlot design. Loafing or bedding areas vary in size and shape according to the same conditions as described above. Confinement barns on manure packs or slats tend to have smaller loafing or bedding areas.

Bedding area management and shade access are also highly variable across and within feedlots. In confinement barns on solid surfaces, bedding is required year around. Bedding cattle in open lots is not easy and creates a manure pack, which affects feedlot pen surface. Yet, the benefits of bedding cattle before and after inclement weather and even during hot summer days are well documented. Similarly, shade and shade area management are not easy in open pens because of the buildup of moisture and mud on the pen surface. Solutions for these two stress-relieving strategies are required on a global basis; yet, ingenious feedlot managers already avail themselves of their own strategies to provide relief without compromising other feedlot functions.

Perhaps waterer site, type, capacity, access, fill line and rate vary more across and within feedlots than pen design itself. In many locations, particularly in confinement barns on slatted floors or open pens in hot and humid areas, water access (defined here as the capacity by any single animal to drink from a waterer within a 2- to 4-hour window in hot weather) not water flow may be a limiting factor in optimizing dry matter (DM) intake. Water quality is another area of concern as total dissolved solids and sulfate concentrations vary by geographic location and source (rural water vs well systems). The reader is referred to an excellent recent review[20] on water quality and consumption, and drinking behavior of cattle for further information on this important subject.

Alternative feed additives — any promising substitutes?

A list of products that may be collectively referred to as eubitoic and currently FDA-approved ionophores and antibiotics for reduction of liver abscesses are listed Table 1. Under regulatory labels, direct-fed microbial (DFM) is the official definition (CPG Sec. 689.100 Direct-Fed Microbial Products) granted by FDA to products that are purported to contain live (viable) micro-organisms (bacteria or yeast). The Association of American Feed Control Officials (AAFCO) describes yeast and yeast culture under section 96, and bacterial and mold ingredients under fermentation products (section 36) of the AAFCO Official Publication.

The position by FDA regarding DFM or fermentation products is that DFM products listed by the AAFCO Official Publication will be regulated as a food as defined in Section 201(f)(3) and usually will not require FDA regulatory attention. However, if FDA has safety concerns about these products, it will treat them as not generally recognized as safe and will regulate them as food additives subject to FDA enforcement attention. Products included in this regulatory position are:

- DFM products listed by the AAFCO Official Publication and labeled with the AAFCO-approved label statement for live microorganism content
- A product containing microorganisms listed by the AAFCO Official Publication but not purported to contain live microorganisms and with no label/promotional representations other than as a source of designated nutrients, and not labeled or promoted with any therapeutic or structure/function claims

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Table 1: Direct-fed microbials and fermentation products and FDA-approved ionophores and liver abscess preventive antibiotics for feedlot use

Product	Class	Active ingredient [a]	FDA indications
Antibiotic	Macrolide	Tylosin	Reduction of incidence of liver abscesses
Antibiotic	Tetracycline	Chlortetracycline	Reduction of liver condemnation due to liver abscesses
Antibody	Polyclonal antibody	Ig Y	None
DFM	Bacterial preparation	Lactobacillus acidophilus	None
DFM	Bacterial preparation	Propionibacterium freudenreichii	None
DFM	Bacterial preparation	Enterococcus faecium	None
DFM	Bacterial preparation	Megasphaera elsdenii	None
DFM	Yeast	Saccharmoyces cerevisiae	None
Essential oils	Essential oils		None
Fermentation product	Enzyme extract	Aspergillus oryzae	None
Fermentation product	Yeast culture	Saccharmoyces cerevisiae	None
Ionophore	Crown ether	Monensin sodium	Improve feed efficiency
Ionophore	Crown ether	Laidlomycin propionate potassium	Improve feed efficiency and increased rate of weight gain
Ionophore	Crown ether	Lasalocid sodium	Improve feed conversion and rate of weight gain

[a] Not a complete list.

Because conventional feedlot production practices are based on use of ionophores and liver abscess-preventive antibiotics,18 a discussion of alternative strategies either in support or in substitution of conventional production practices would not be complete without establishing a baseline of the impact of ionophores and liver abscess-preventive effect on feedlot performance. Therefore, alternative feed additive solutions to be used in conjunction with or as substitutes of existing feed additives, they would need to meet certain minimum requirements of which maintaining cattle performance at levels expected for conventional feed additives may only be one of the considerations. In an effort to lead the reader to reflect on a holistic evaluation of alternative feed additives presented in the following sections, a list of the ideal feed additives, based on the feedlot industry experience with conventional feed additives, is drawn in Table 2.

A meta-analysis[3] of effects of monensin on performance of feedlot cattle published nearly 10 years after the molecule was FDA approved demonstrated that cattle fed monensin had 7.2% improved feed conversion with 2.7% lower DM intake. Later, using a meta-analysis approach evaluating all three ionophores listed in Table 1, DiCostanzo et al2 reported that feedlot cattle fed laidlomycin, monensin or lasalocid required less feed DM/unit gain. This reduction resulted in improvements in feed efficiency of 5.4%, 4.6%, 5.7% and 6.7% for laidlomycin, lasalocid, monensin or monensin plus tylosin, respectively. Given differences in feed DM unit/unit gain for cattle fed no ionophore in these studies, it behooves the authors to present reductions in feed DM unit/unit gain as absolute values; 0.583 and from 0.29 to 0.46 feed DM unit/unit gain[2]. Recent reports on the impact of ionophore feeding on feed conversion revealed that both monensin and laidlomycin reduced feed DM/unit gain by 0.22 and 0.20, respectively, relative to control groups.

Tylosin is an effective antibiotic for prevention of liver abscesses. Cattle fed no tylosin, including those fed monensin, laidlomycin or lasalocid, had an incidence of liver abscesses close to 30%, yet only 10% of cattle fed tylosin alone or in combination with monensin had liver abscesses[2]; a reduction of 65%. Similarly, a recent summary[6] of 40 studies demonstrated that cattle fed tylosin had liver abscess incidence 73% lower than that of cattle not fed tylosin. Although not as effective as tylosin, chlortetracycline reduced liver abscess incidence 43% in a recent summary of data by Zoetis.

Because 90% feedlots surveyed recently[18] reported using ionophores, productivity of the modern feedlot is dependent on these molecules to the extent of their impact on performance and health of cattle. Further, field inclusion of these molecules became second-nature to the feed and drug manufacturing industry servicing the feedlots in the U.S. and the world. Storage type, and warehouse capacity, product transfers between warehouse, mixing and user facilities, suspension of dry or liquid supplements or direct inclusion in finished diets and the network necessary to support provision of these molecules to an industry with a one-time capacity of 11 million cattle are important considerations when evaluating alternative feed additives in support or in substitution for conventional FDA approved ionophores and antibiotics. Inclusion rate alone may become a limiting factor for alternative feed additives that are required at more than 1 g/head daily. For example, if one would consider full substitution of monensin with a product that is required at 1 g/head daily, production, storage and transfer required by the

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Table 2: Proposed "ideal" traits for eubiotic feed additives to substitute or supplement ionophore and liver abscess preventive antibiotics

Performance indicator	Improvement over control	
	Minimum	**Optimum**
ADG	0%	3%
DMI	0%	-3%
Feed DM/unit gain	-2%	-4%
Liver abscess incidence	-45%	-75%
Other characteristics		
Clear indications for storage and use		
Dry feed delivery		
Easy flow		
Impervious to environmental conditions		
Liquid feed delivery		
Long mixed-in shelf-life		
Long shelf-life		
Low inclusion		
Low or no associative effects with feed ingredients		
Micro-ingredient delivery		
Regulatory oversight		
Small particle size		

industry would increase 3-fold! One can only imagine the public outrage; this time it would be aimed at the projected carbon footprint of the substitute feed additive.

Interest generated by the desire to develop effective non-antibiotic feed additives for the prevention of liver abscesses led to completion of many studies in recent years. A list of studies evaluating various non-antibiotic feed additives for prevention of liver abscesses is provided in Table 3; their effect on incidence of liver abscesses will be discussed in an order based on the number references listed within each category.

Preparations based on Saccharomyces cerevisiae are marketed by various companies as active dry yeast or as the fermentation product of yeast cells (not containing active cells). Various authors have studied fermentation products (SCFP) and one research group studied active yeast (ADY) as-is or encapsulated[12] (Table 3).

Initial results with fermentation products of Saccharomyces cerevisiae[14] were positive; no differences were detected in incidence of liver abscesses between cattle fed a conventional supplement and those fed the SCFP (Table 3). Yet, taken together, results from two large studies[5,21] listed in Table 4 revealed differences in liver abscess incidence between cattle fed tylosin and those fed SCFP, and both studies revealed that there were no differences between cattle fed no tylosin and those fed SCFP. Results from Shen et al15 were based on 15 head of individually fed cattle: one abscessed liver in a treatment contributes 6.66% to the total incidence.

Similarly, feeding active dry yeast[12] encapsulated or not, had no effect on liver abscess incidence (Table 3). In this study, 75 head were allocated to five treatments. Therefore, one abscessed liver in a treatment also contributed 6.66% to the total incidence of liver abscesses.

Various preparations of organic minerals with pre- or probiotics were tested (Table 3). In two studies,[4, 22] tylosin-based supplements served as positive control. In both those studies, feeding tylosin led to lower incidence of liver abscesses than feeding the mineral-biotic combination. In another large study[10] conducted with cattle fed no feed additives, the mineral-biotic combination was ineffective at reducing incidence of liver abscesses in steers or heifers (Table 3).

Results from a large study[21] demonstrated essential oils were ineffective at preventing liver abscesses while another study11 with 72 head revealed no differences in incidence of liver abscesses between essential oil treatment and negative or positive control (Table 3).

A study[16] with 77 Holstein steers presenting with a large incidence of liver abscesses failed to demonstrate a difference between cattle fed tylosin and those fed a preparation containing immunoglobulin-Y. Use of a-tocopherol and ascorbic acid to prevent liver abscesses (Table 3) was also ineffective.[7] Lastly, a study with 495 head from Argentina1 provided some evidence for tannins to prevent liver abscesses although incidence of liver abscesses was extremely low (Table 3).

In spite of efforts to develop alternatives to antibiotic feed additive use for prevention of liver abscesses, this review of published results revealed no evidence of a given non-antibiotic feed additive that reduces liver abscess incidence. This is not surprising. In spite of large strides in identifying bacteria responsible for generating liver abscesses and in recognizing certain factors that contribute to development of liver abscesses, our understanding of the precise timing and pathways of development of liver abscesses is not complete. Further, we do not know what role, if any, cofactors such as minerals, vitamins, antioxidants, or pre- or probiotics may play in preventing liver abscess development. Access to large groups of cattle, facilities and equipment to conduct these experiments adds to this challenge.

Moisture content of feeds — an inherent variable affecting feed delivery

Assuming a perfectly filled batch-sheet load requirement onto a perfectly calibrated scale on a mixer parked on the level loaded within limits and mixed for the appropriate time, followed by perfect pen delivery accuracy (both site and amount), inherent nutrient composition variation, particularly DM (or moisture) content has the potential to generate DM delivery deviations. In practice, the effect of differences in moisture concentration of feed is considered minimal or it is ignored.

Furthermore, results from the most recent Feedlot Monitoring survey by USDA NAHMS[17] revealed that 63% and 34% of feedlots stored hay and silage, respectively, uncovered on piles, bunks or pits. It is also interesting to note that 58% of feedlots responded that co-products from ethanol production are stored uncovered. The consequences of this practice are not documented. Research studies documenting DM or nutrient loss from feed exposed to the elements exist but performance implications of changes in diet DM composition resulting from changes in moisture content of one or more ingredients has not been studied.

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Table 3: Effects of active dry yeast (ADY), antioxidants (a-tocopherol and ascorbic acid), essential oils (EO), organic minerals with or without biotic additives (Minerals +), Saccharomyces cerevisiae fermentation products (SCFP) or tannins on incidence (%) of liver abscesses regardless of severity (adapted from various sources)

Product tested	Total head	Negative control	Tylosin	Product tested	*P*-value	Reference	Year
ADY	75	46.7	60.0	60.0	0.75	12	2018
ADY	75	46.7	60.0	46.7	0.75	12	2018
Antioxidants	392	25.7	NA	23.6	0.63	7	2018
EO	5481	23.7	15.0	24.5	0.004	21	2017
EO	72	12.8	12.5	16.8	0.88	11	2019
IGY	77	NA	65.4	48.2	0.21	16	2021
Minerals +	1680	NA	13.6	26.5	0.001	4	2016
Minerals +	600	21.3	7.7	20.3	0.01	22	2018
Minerals +	2879[a]	38.7	NA	37.1	0.44	10	2020
Minerals +	4799[b]	28.7	NA	35.2	0.84	10	2020
SCFP	1495	NA	20.9	16.3	0.27	14	2017
SCFP	5481	23.7	15.0	22.3	0.004	21	2017
SCFP	4689	38.9	NA	38.1	0.79	5	2019
SCFP	90	66.7	60.0	60.0	0.97	15	2019
Tannins	495	5.9	NA	1.2	0.005	1	2019

Approximated number of heifers [a] and steers [b]

Feed ingredient DM content measured at various frequencies at feedlots in the Upper Midwest (Table 4) represent a wide range between feedlots, between feed ingredients and, likely, between frequency of determination. All feed ingredients listed in Table 4 were stored in bunkers (fermented feeds) or storage bays (distillers grains and solubles). Hay was processed through a hay grinder and piled outdoors on a bituminous surface. Average DM content within feed ingredient across feedlot varied by 10 points likely reflecting location, growing and harvest conditions.

Although also dependent on sampling frequency, within feed ingredient type, variance (average degree to which each sample differs from the mean) of feed ingredients tends to be larger for feed ingredients high greater moisture content (Table 4). The standard deviation—a measure of spread from the mean — is determined by taking the square root of the variance. Thus, standard deviations increase at a slower rate than variances. Therefore, within or across feed ingredients, those with larger variances do not necessarily display larger standard deviations.

A third measure of dispersion is listed in Table 4: the coefficient of variation (standard deviation divided by average). Common quality control guidelines within nutrition laboratory procedures, dictate that a coefficient of variation of 5% or less is considered adequate. Using this approach to judge the range in variability of feed ingredient samples in Table 4, one would conclude that, generally, variation in DM content of various feed ingredients is relatively low or rather within limits applied to quality control of laboratory procedures. Even for a co-product such as distillers grains and solubles or high-moisture harvest of corn or corn, cobs, husks (earlage), variation around the mean was within 5%. Some corn silage samples also had CV lower than 5%. In contrast, other less used feed ingredients such as oatlage or cull potatoes had CV greater than 5%. The effect of weather on feed ingredients is demonstrated with the hay sample collection listed in Table 4.

Adjusting as-fed dietary composition based on daily hay and every-other-day corn silage and high-moisture corn DM determinations, had no effect ($P > 0.05$) on performance of yearling cattle (VanDerWal, unpublished). In that study, as-fed dietary composition of control pen diets reflected once monthly DM determinations.

A key finding in that study was that variability of feed delivery was actually greater for pens under the more frequent as-fed dietary composition adjustment. This prompted implementation of a modelling study. A modelling of simulations was used to determine the effects of frequent (daily) or infrequent (once or never) adjustment to as-fed dietary composition, in response to changes in observed ingredient DM content, on dietary DM composition and DM delivery. Dry matter content of high-moisture corn, corn silage and modified- or wet distillers grains and solubles from Table 4 was used to formulate two diets: high-forage, backgrounding diet or high-energy, finishing diet. Target dietary DM composition were (backgrounding or finishing diet, respectively): grass hay (20% or 4%), corn silage (55% or 9%), high-moisture corn (10% or 52%), distillers grains with solubles (12% in either diet), dry rolled corn (0% or 20%) and supplement (3% in either diet). Feed delivery periods lasting 84 days were simulated. Target deliveries of 25 lb DM/head of each diet (dietary treatment) were simulated to occur once daily to 400 head (10,000 lb DM) with a scale sensitivity of 5 lb (as-fed) per load.

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Table 4: Means and measures of sample dispersion for DM content of various feed ingredients sampled at various feedlots in the Upper Midwest

Feed	Sampling frequency	*n*	Average, %	Variance, %2	Standard deviation, %	Coefficient of variation, %
Corn grain	Daily	95	72.87	0.04	2.10	2.88
Corn grain	Daily	87	61.74	0.22	4.66	7.55
Corn grain	Thrice a	51	71.61	0.08	2.78	3.89
Corn silage	Daily	93	30.76	0.03	1.77	5.75
Corn silage	Daily	87	35.80	0.14	3.75	10.48
Corn silage	Thrice	39	36.03	0.03	1.78	4.93
Corn silage	Thrice	51	41.41	0.12	3.44	8.30
Corn silage	Weekly	68	32.58	0.05	2.34	7.19
Distillers	Daily	95	49.12	0.06	2.35	4.78
Distillers	Thrice	39	27.79	0.01	1.01	3.64
Distillers	Thrice	51	51.22	0.02	1.25	2.44
Distillers	Weekly	68	50.24	0.05	2.33	4.63
Earlage	Thrice	39	58.82	0.03	1.65	2.81
Earlage	Weekly	68	61.06	0.02	1.31	2.15
Hay[b]	Daily	84	76.94	1.35	11.61	15.09
Oatlage	Daily	95	40.18	0.07	2.70	6.71
Potatoes	Weekly	68	44.03	0.34	5.86	13.31

[a] Thrice weekly.
[b] Processed and stored outdoors on a bituminous surface.

Strategies simulated never adjusting as-fed dietary composition based on DM content from book values[8] initially or adjusting as-fed dietary composition in response to monthly, weekly, daily or averaged (three-week average of weekly determinations) DM content determinations. Significant ($P < 0.05$) departures from target dietary corn silage, high-moisture corn and supplement DM content, regardless of diet, were greater when as-fed dietary composition was never adjusted. Monthly adjustments to as-fed dietary composition, regardless of diet, also resulted in significant ($P < 0.05$) departures from target dietary corn silage and supplement DM content. Adjusting as-fed dietary composition in response to weekly or daily DM determination or the three-week average generally led to lowest departures from target dietary corn silage and high-moisture corn DM content. The magnitude of these departures was largest for corn silage (from 1 to 2 percentage units), followed by those observed for high-moisture corn and distillers grains and solubles (from 0.5 to 1 percentage unit).

Bunk call size (standardized amount of feed to increase or decrease pen delivery daily) varies depending on feedlot policies driven dietary energy and moisture content, days on feed, cattle type and weight, health status, weather and, likely, other factors. Although in the simulation, DM delivery remained constant (to permit departures to be easily detected), the simulation established a tolerance for departures of 1 lb DM/head daily. This value represented 4% of targeted DM delivery. Frequency of days in which DM delivery departed 1 lb/head from either the target delivery (25 lb/head) or previous day delivery (25 lb ± lb previous day deviation) were calculated and subjected to statistical analysis. Simulated feeding of diets for which there was never an as-fed dietary composition adjustment had the greatest proportion (48%) of days where DM deliveries departed more than 1 lb/head relative to target delivery. Adjusting as-fed dietary composition daily resulted in the greatest frequency (39%) of days when DM deliveries departed more than 1 lb/head from the previous day. Analysis of the additive frequency resulting from departing by more than 1 lb DM/head from target or the previous day indicated that never adjusting as-fed dietary composition or adjusting as-fed dietary composition daily led to the greatest ($P < 0.05$) additive frequency (58% or 53%, respectively). Additive frequency of departing by more than 1 lb DM/head from target or from the previous day was least (42%) for dietary as-fed composition adjusted weekly based on the previous three-week average. Adjusting as-fed dietary composition resulting from monthly or weekly DM determinations led to intermediate additive frequency of departures greater than 1 lb DM/head from target or the previous day (47% or 48%, respectively).

If the additive frequency of generating departures greater than 1 lb DM/head from target delivery or the previous day is 42%, then, assuming most feedlot steers require 4,000 lb of DM and 171 days to finish, frequency of deliveries will be off due to one condition or the other during 72 days. Because tolerance in this simulation was set to 1 lb DM/head, DM deliveries over 171 days are expected to be off by at least 1 lb/day during 72 days or 0.42 lb DM/head (≥ 72 lb/4,000 lb). Under the conditions of this

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simulation, we determined that bunk calls have a built-in margin of 0.42 lb. This margin is simply due to random variation caused by fluctuations in DM content of the three ingredients modelled: it does not include head count, mixing or delivery errors. Neglecting to measure DM content of feeds and adjust as-fed dietary composition accordingly has the potential to increase this margin of error to within 0.60 lb/head daily.

What should be gleaned from this observation is that when a bunk call is made, a potential exists for exaggerating the value of the bunk call by ± 0.42 to 0.60 lb DM/head daily depending on the feedlot's policy to adjust as-fed dietary composition in response to changes in DM content of ingredients. During receiving or weather forecasts that reduce intake, aggressive bunk calls (0.50 lb DM/head or greater) have the potential to generate larger swings in feed delivery. This suggests that bunk calls greater than 0.75 lb DM/head are recommended only when cattle are expected to endure DM intake swings greater than 1 lb/head daily. This situation is likely present when cattle are past the initial grower diet steps and heading into cooler weather patterns. As it will be demonstrated below, this built-in fluctuation in dietary DM delivery and response by the feeder to bunk scores interact to create large swings in DM intake particularly during weather events.

Bunk calls — the human element of scoring bunks

When reviewing intake (or feed delivery) curves that resemble a serrated blade, the consultant will often look for the one event that may have led to this pattern often concluding that a change in diet, a mistake in loading, mixing, feed delivery, bunk call or weather event led to it. Yet, in many cases, it is not a single event that determines this outcome but a continued series of events. These events likely result from inconsistent diet composition resulting from moisture content changes, as was already demonstrated above, and inconsistent or aggressive bunk calls or both.

The action of delivering feed is the result of nearly split-second responses by humans to feed ingredient-related and animal-associated factors, and to their own perception of the environment and the animal. Because of the difficulties associated with measuring and analyzing these actions and reactions in real time, it has been difficult to understand to what extent these influence DM intake.

A DM intake curve from a given pen is simply reflecting the outcome of these complex interactions. For a deeper understanding of human behavior while delivering feed to cattle, one should bring together at least three elements: bunk score, bunk call and resulting feed delivery or feed intake curve. Feed delivery curves only represent feed intake curves when feed refusals (feed left in the bunk) are at or near zero or when feed refusals are removed, weighed and their DM determined to subtract feed refusal from feed delivery as it is supposed to be done in feedlot research studies.

Bunk calls are seldom graphed, and bunk scores are only used, if collected and saved, to determine recent trends in feed removal from the bunk. The theoretical assumption is that if bunk scores are near zero daily, slick bunk conditions are achieved and no further adjustments are necessary. In practice, everyone knows bunk scores of zero throughout an entire feeding period are the exception not the rule. Understanding the role of human behavior in responding to bunk scores may provide an added clue to actions that lead to fluctuating DM intake. Though not all humans can or should be expected to behave in the same exact fashion as another human, recognizing differences in response by some individuals may help reduce variation between individuals within or across feeding crews.

An example of a bunk call plot in response to bunk scores is provided in Figure 1. It represents a narrow window in the progression of feeding a pen of research cattle from the spring into the summer of 2020. The pen was selected from a large group of pens to demonstrate the concept of human response to bunk scores. The information gleaned from this plot is intended to serve as evidence of what may occur within a feedlot when bunk calls are made by different people as may be the case during weekends, vacations or where more than one individual scores bunks.

The Y-axis represents the amount (lb DM/head) the bunk reader calls based on the bunk score they observed (Z-axis; right side vertical axis on a scale of 0 to 4). The horizontal axis represents days of the summer of 2020 in Rosemount, Minn. Temperature at or above 85°F and increases with high humidity (> 70%) were observed from 6/16/20 to 6/19/20, from 6/26/20 to 6/29/20 and from 7/1/20 to 7/6/20. A person substituted the main feeder (Sub) and scored bunks and made bunk calls from 6/8/20 to 6/20/20; the main feeder (Main) returned on 6/21/20 and continued scoring and calling bunks.

Bunk calls made by Sub from 6/14/20 to 6/20/20 were unchanged and remained at 26 lb DM/head). The expectation of high temperatures evident from checking forecast online led Sub to make no changes to bunk calls. On 6/21/20, Main calls for an additional 0.50 lb DM/head in spite of two situations: 1) bunk was scored at 0.1 on 6/18/20 and 6/19/20 (in this feedlot, a score of 0.10 is implemented to serve as warning not to change bunk call or to consider a reduction in the call) and 2) weather forecast indicated a high probability of heat and humidity on 6/21/20 already. After two consecutive bunk scores of 0, generally a trigger to increase bunk call in this feedlot, Main decided to increase bunk call to 27 lb DM/head on 6/24/20. Now, the impending weather change for higher heat and humidity is only a week away. This bunk call is repeated on 6/25/20. By 6/26/20, Main calls for a drop of 1.5 lb DM/head in bunk call. This response was obviously delayed; bunks continued to have greater bunk scores starting on 6/27/20 and posted a score of 2 on 6/29/20. By then, Main has had to adjust bunk calls down from the peak of 27 lb DM/head reached on 6/25/20 down to 22.7 lb DM/head on 6/28/20, then to 22.2 lb DM/head on 7/2/20, and to 19.5 lb DM/head on 7/5/20. Resulting DM intakes (feed refusals weighed) were 25.9 lb DM/head for the period between 6/14/20 and 6/20/20, 26 lb DM/head for the period between 6/21/20 and 6/27/20, 22.3 lb DM/head for the period between 6/28/20 and 7/4/20 and 19.6 lb DM/head for the period between 7/5/20 and 7/11/20. These cattle were marketed on August 19, 2020; their intake never recovered.

Currently, we are analyzing data from various studies to understand to what extent bunk calls resulting from human responses to bunk scores create DM intake fluctuations and what the effect on performance is. It is clear that bunk calls depend on the feeder's attitude to manage cattle. Because the focus of cattle feeding has been on maximizing intake, the expectation is that feeders may tend to be aggressive on bunk calls.

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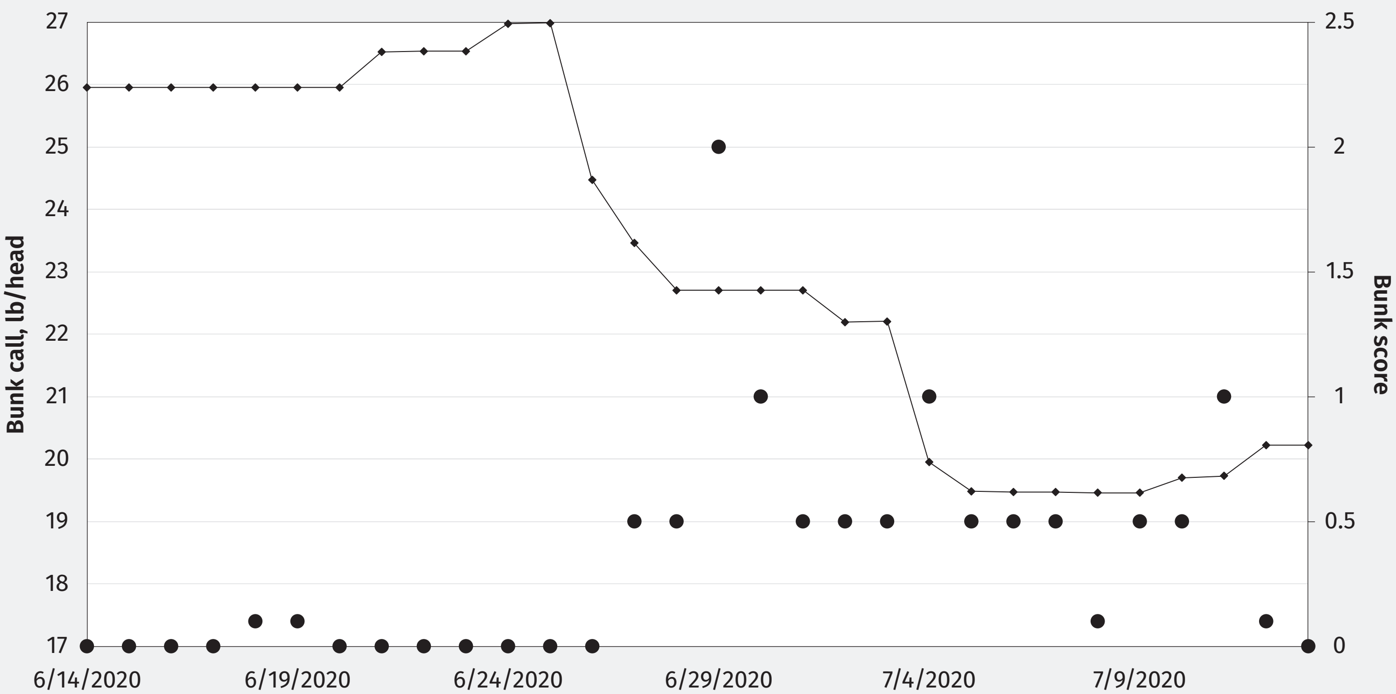
Figure 1: Analysis of bunk calls (lb/head) resulting from bunk calls (Z-axis; right vertical on a scale of 0 to 4) made by a substitute feeder between 6/14/20 and 6/20/20 and the main feeder (remaining of dates displayed).



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