

Association between changes in eating and drinking behaviors and respiratory tract disease in newly arrived calves at a feedlot

Marilyn J. Buhman, DVM, MS; Louis J. Perino, DVM, PhD; Michael L. Galyean, PhD; Thomas E. Wittum, PhD; Ted H. Montgomery, PhD; R. Spencer Swingle, PhD

Objective—To investigate eating and drinking behaviors and their association with bovine respiratory disease complex (BRDC) and to evaluate methods of diagnosing BRDC.

Animals—170 newly arrived calves at a feedlot.

Procedure—Eating and drinking behaviors of calves were recorded at a feedlot. Calves with clinical signs of BRDC were removed from their pen and classified retrospectively as sick or not sick on the basis of results of physical and hematologic examinations. Pulmonary lesions of all calves were assessed at slaughter.

Results—Calves that were sick had significantly greater frequency and duration of drinking 4 to 5 days after arrival than calves that were not sick. Sick calves had significantly lower frequency and duration of eating and drinking 11 to 27 days after arrival but had significantly greater frequency of eating 28 to 57 days after arrival than calves that were not sick. Calves at slaughter that had a higher percentage of lung tissue with pneumonic lesions had significantly lower frequency and duration of eating 11 to 27 days after arrival but had significantly higher frequency and duration of eating 28 to 57 days after arrival. Agreement for calves being sick and having severe pulmonary lesions at slaughter was adequate. Agreement for calves being removed and having pulmonary lesions at slaughter was low.

Conclusions and Clinical Relevance—Eating and drinking behaviors were associated with signs of BRDC, but there was not an obvious predictive association between signs of BRDC in calves and eating and drinking behaviors. Fair to poor agreement was observed between antemortem and postmortem disease classification. (*Am J Vet Res* 2000;61:1163–1168)

Bovine respiratory disease complex (BRDC)

accounts for the highest number of illnesses and

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From the Division of Agriculture, West Texas A&M University, Canyon, TX 79016 (Buhman, Perino, Galyean, Montgomery); the Department of Veterinary Preventive Medicine, College of Veterinary Medicine, The Ohio State University, Columbus, OH 43210 (Wittum); and Cactus Feeders, PO Box 3050, Amarillo, TX 79106 (Swingle). Dr. Buhman's present address is University of Nebraska-Lincoln, Great Plains Veterinary Educational Center, Clay Center, NE 68933. Dr. Galyean's present address is Animal Science and Food Technology Department, College of Agriculture and Natural Resources, Texas Tech University, Lubbock, TX 79409. Supported in part by a grant from Roche Vitamins Inc.

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Address correspondence to Dr. Perino.

fatalities in feedlot cattle.¹ Owners and managers of feedlots recognize the financial loss caused by BRDC and are constantly seeking to improve methods of diagnosis and treatment for BRDC.

It is evident to experienced animal handlers that the behavior of sick cattle differs distinctly from that of healthy cattle. However, there is little documented information concerning the eating and drinking behaviors of sick calves. In an extensive review of the behavior of sick animals,² investigators reported that animals have several nonimmunologic disease-fighting strategies, 1 of which is behavioral reactions. In feedlots, experienced personnel use changes in eating and drinking behaviors as signs of illness. Sowell et al^{3,4} suggested that sick calves requiring treatment do not eat as aggressively as nontreated calves and tend to be anorectic. Recent development of an electronic monitoring system^{3,a} allows continuous observation of eating and drinking behaviors of sick and healthy cattle without disruption of typical behaviors.

Current methods of diagnosing BRDC involve the use of a combination of subjective and objective signs as well as results of clinicopathologic examinations.⁵⁻⁸ Analysis of results suggests that these methods are not adequate to prevent substantial production losses attributable to respiratory tract disease.⁹ The positive-predictive value, negative-predictive value, κ , odds ratio, sensitivity, and specificity of measurements used to diagnose BRDC have not been investigated and reported. The purposes of the study reported here were to investigate the association between behaviors involving eating and drinking and BRDC in calves and to evaluate methods of diagnosing BRDC.

Materials and Methods

Animals—Two groups of heifer calves were observed throughout the first 57 or 62 days after arrival at a feedlot (day of arrival = day 0). The first group of 85 calves originated from auction markets in the southeastern United States (10 auction markets in 2 states) and subjectively was classified by feedlot personnel as being at high risk for developing BRDC. The calves arrived at the feedlot in November 1997 with a mean \pm SD body weight of 249.5 \pm 15.64 kg. Calves were processed within 12 hours after arrival and received a vaccine^b that contained modified-live infectious bovine rhinotracheitis (IBR) virus, killed bovine viral diarrhoea virus (BVDV), and killed parainfluenza-3 (PI-3) virus, a vaccine^c administered nasally that contained modified-live IBR and PI-3 virus, a bacterin-toxoid^d against *Mannheimia haemolytica* (formerly *Pasteurella haemolytica*), a multivalent bacterin-toxoid^e against 7 clostridial species, a macrolide antibiotic,^f a doramectin dewormer,^g an orally administered probiotic, yeast, and vitamin drench,^h and an estradiol ben-

zoate-testosterone implant.¹ Calves were given a booster with a modified-live vaccine¹ against IBR virus 8 days after arrival.

The second group of 85 calves originated from auction markets in the southeastern United States and subjectively was classified by personnel at the feedlot as being at high risk for developing BRDC. These calves arrived at the feedlot in January 1998 with a mean body weight of 234.5 ± 18.18 kg. Calves were processed within 6 hours after arrival and received the same processing regimen as the first group of calves, except the second group of calves did not receive a bacterin-toxoid^d against *Mannheimia haemolytica*; however, they did receive 2 multivalent bacterin-toxoids^{e,k} against 7 clostridial species and a zeranol implant.¹ All calves had an electronic identification device placed in 1 of their ears. A study of clostridial vaccines was superimposed on this observational study.¹⁰ Initial body weight, electronic identification number, dehorning or tipping of horns, and any specific identification items (tags from auction markets, ear tags for vaccination against brucellosis, or coat color) were recorded at processing.

Feedlot—This study was conducted at a 40,000-calf capacity commercial feedlot located near Hereford, Tex. Management was typical for a feedlot of this size.

Collection of data on eating and drinking—Data on eating and drinking behavior were collected, using an electronic monitoring system.^a Mean duration of eating and drinking recorded during this study was the duration of time spent at the feedbunk or waterer. An eating or drinking event was defined as the presence of a calf at the feedbunk or waterer for ≥ 5.25 seconds, with a new eating or drinking event recorded if the calf left the feedbunk or waterer for ≥ 300 seconds but subsequently returned. Data for calves that were removed or missing from their pen for ≥ 2 hours on a specific day were deleted for that day.

For analysis, eating and drinking behaviors of calves were summarized for 5 arbitrarily determined time periods (1 to 3, 4 to 5, 6 to 10, 11 to 27, and 28 to 57 days after arrival). For each of these time periods, mean daily frequency and duration of eating and drinking was calculated for each calf in the study population.

Collection of data on weight gain—Body weight of each calf of the first group was recorded on days 0 and 62 of the study, and body weight of each calf in the second group was recorded on days 0 and 57. **Mean daily gain (MDG)** for each calf was calculated for the initial 57 or 62 days of the feeding period. Mean daily gain for the entire feeding period was calculated by use of the following equation:

$$\frac{[\text{hot carcass weight of calf/dressing percentage of pen}] - \text{arrival weight of calf}}{\text{No. of days at feedlot}}$$

Collection of data on feed—Data for daily feed activities were collected, including time of feed deliveries, quantity of feed delivered, and diet composition. Both groups of calves were sequentially fed 4 diets. The initial diet contained approximately 37% roughage and 73% concentrate and was formulated to contain 78 to 80% dry matter, 1.10 Mcal of net energy for gain (NEg)/kg, and 13.5% crude protein on a dry-matter basis. The final diet was formulated to contain 78 to 80% dry matter, 1.54 Mcal of NEg/kg, 13.5 to 14.0% crude protein on a dry-matter basis, and 13% roughage and 87% concentrate. The first group of calves was fed for 214 days, and the second group was fed for 190 days. Daily rate of feed intake was calculated for each group of calves, using the following equation:

$$\frac{\text{(amount of feed delivered to pen/No. of calves in pen)}}{\text{average eating duration}}$$

Collection of data on health of calves—Calves were observed daily by experienced feedlot personnel for clinical signs of BRDC. Identification of calves removed from their pen and treatment regimen implemented for calves removed because of BRDC were recorded. The BRDC treatment regimen was one typically used by feedlot personnel. All calves that were removed for BRDC received antimicrobial treatment in accordance with protocols established by the attending veterinarian. Calves were classified as chronic cases of BRDC when they failed to recover after 3 treatments were administered. Identification of each calf that died was recorded, and gross necropsy was performed on each calf that died.

All calves that were removed because they had clinical signs of BRDC were given a physical examination. A blood sample was obtained on the day they were removed and again on the day they were returned to their pen. When treatment resulted in the calf being removed and returned to its pen on the same day, only 1 physical examination and blood sample were obtained. Physical examinations were conducted in the treatment chute, without time constraints placed on the personnel performing the examinations. Blood samples from each calf were obtained via jugular venipuncture into an evacuated tube that did not contain additives^m and an evacuated tube that contained EDTA.ⁿ Objective data collected at the treatment chute on calves removed because of BRDC included body weight, rectal temperature, respiratory rate, and values for nasal pulse oximetry. Subjective data collected on calves removed because of BRDC included ruminal fill (1 = normal, 2 = slightly gaunt, 3 = moderately gaunt, 4 = excessively gaunt), attitude (1 = normal, 2 = slight lethargy, 3 = severe lethargy, 4 = nonambulatory), ocular discharge (1 = none, 2 = slight, 3 = moderate, 4 = abundant), nasal discharge (1 = none, 2 = slight, 3 = moderate, 4 = abundant), and results for auscultation of each lung at 3 sites that were along a line extending from the cranioventral to caudodorsal lung fields (1 = normal, 2 = slightly harsh, 3 = moderately harsh, 4 = severely harsh). Data collected on the second group of calves also included auscultation of the trachea (1 = normal, 2 = slightly harsh, 3 = moderately harsh, 4 = severely harsh). Measurements were obtained at a standard time relative to removal of calves from their pen and time of day. Calves were independently scored by the evaluators at the outset and at intervals throughout the study to standardize the scoring system to the best extent possible. Calves were moved from a holding pen to the chute in small groups (≤ 4 calves/group) to minimize the effect of prolonged waiting on rectal temperature.

Data for laboratory analyses—Laboratory analyses of blood samples included determination of **serum concentrations of total protein (STP)** and haptoglobin, total WBC count, differential WBC count, PCV, and **plasma total protein (PTP)** concentration. The STP concentration was determined by manual use of a refractometer, using serum obtained after centrifugation ($3,146 \times g$ for 30 minutes) of clotted blood samples. A 2.0-ml aliquot of serum was frozen at -18 C for subsequent determination of serum haptoglobin concentration.¹¹ Haptoglobin concentrations were determined indirectly.^o Concentration for a blank haptoglobin vial was subtracted from the concentration in a blood sample, and the resulting difference was multiplied by a conversion factor; the product was compared with values on a standard curve to determine the haptoglobin concentration. Total WBC was determined from the EDTA-containing blood sample, using a manual system.^p Differential WBC count was determined, using the EDTA-containing blood sample and a commercial leukocyte stain.^q To determine PCV, a heparinized microhematocrit capillary tube^r was filled (three-

quarters full) with blood from the EDTA-containing tube, centrifuged at $3,146 \times g$ for 30 minutes, and then evaluated.⁵ The PTP concentration was determined, using a refractometer, from plasma in the microhematocrit capillary tube that had been used for the PCV determination.

Health classification—A scoring system was developed to retrospectively classify removed calves as sick or not sick at time of first removal. A calf received 1 point for each of the following variables: rectal temperature ≥ 40.0 C, ruminal fill ≥ 3 , attitude ≥ 3 , combination of the nasal and ocular discharge ≥ 5 , lung auscultation score for either lung ≥ 5 , pulse oximetry ≤ 85 , total WBC $\geq 12,000$ cells/ μ l, and haptoglobin concentration ≥ 15 mg/dl. Haptoglobin concentration was not used in the classification of calves until 5 days after arrival. Calves receiving ≥ 3 points at time of first removal were classified as sick. This resulted in 3 health categories: not removed from the pen, removed from the pen and not sick, and removed from the pen and sick.

Data from the slaughter facility—Cattle were marketed in a typical manner for the feedlot. Data collected at the slaughter facility included slaughter sequence, electronic identification number, pulmonary lesions,¹² and hot carcass weight. One evaluator who was unaware of the category of each calf (LJP) scored the lungs on the basis of total lung involvement (0% = no pulmonary lesions, < 20% = minor pulmonary lesions, $\geq 20\%$ = major pulmonary lesions). The investigator used a standardized scoring sheet and description of lesion classifications. Identification was misplaced on 24 pairs of lungs, making them unavailable for scoring.

Statistical analysis—Outcomes of interest were measures of clinical and subclinical respiratory tract disease and growth performance in the study population. For this analysis, calves were classified as having clinical respiratory tract disease when they were removed for treatment and retrospectively classified as sick on the basis of the previously described scoring system. The percentage of pulmonary tissue involved with pneumonic lesions at slaughter was used as an indicator of respiratory tract disease that was not identified or not resolved by treatment. Mean daily gain for the entire feeding period in the feedlot was used to indicate growth performance.

Associations between eating and drinking behaviors and the outcomes of interest were assessed, using multivariable methods. Logistic regression procedures⁷ were used to evaluate clinical respiratory tract disease. An ANOVA procedure⁸ was used to identify associations of behaviors with MDG and with percentage of pulmonary tissue involved with pneumonic lesions. Because of suspected high colinearity among variables, separate models were developed to determine the independent associations of each of the 4 behaviors (eating frequency, eating duration, drinking frequency, and drinking duration) with the outcomes of interest. A variable indicating the group replicate was forced into all models. Final models were developed by initially fitting a model that contained all 5 time-period variables for each specific behavior. Time periods not associated with outcomes were removed, using a backward selection procedure¹³ with a criterion of $P \leq 0.05$ to remain in the model. Estimates of differences in behavior between calves that were sick and those that were not sick were obtained, using an ANOVA¹ with behavior as the outcome variable. Variables indicating body weight at time of arrival and clostridial vaccine group were tested as potential confounders in each model and removed if not associated with the outcome. Clinical respiratory tract disease was tested as a potential confounder when evaluating the effects of behavior on MDG.

The κ as well as positive- and negative-predictive values were calculated for sickness status versus final percentage of pulmonary lesions and removal status versus final percentage of pulmonary lesions. The McNemar χ^2 test⁹ for bias was calculated for sickness status versus final percentage of pulmonary lesions and removal status versus final percentage of pulmonary lesions.

Results

Of 170 calves, 43 (25%) were removed and treated for BRDC. Distribution of initial detection of respiratory tract disease, on the basis of number of days in the feedlot, was determined (Fig 1). Mean frequency of eating (Fig 2), duration of eating (Fig 3), frequency of drinking (Fig 4), and duration of drinking (Fig 5) for calves that were sick, not sick, and not removed were determined.

Frequency and duration of drinking was significantly higher 4 to 5 days after arrival for calves that were sick than for calves that were not sick. Frequency and duration of eating and frequency and duration of drinking were significantly lower 11 to 27 days after arrival for calves that were sick; however, 28 to 57 days after arrival frequency of eating was significantly higher. Least-squares means for associations between sickness status and behaviors regarding eating and drinking were calculated (Table 1).

Calves at slaughter with a higher percentage of

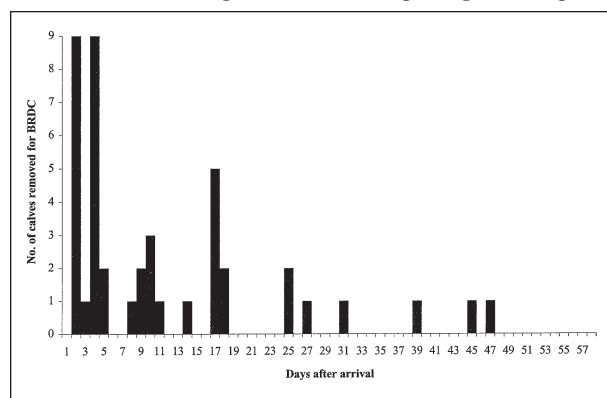


Figure 1—Graph depicting the No. of days after arrival when respiratory tract disease in newly arrived calves at a feedlot was initially detected and calves were removed for examination and treatment. BRDC = Bovine respiratory disease complex.

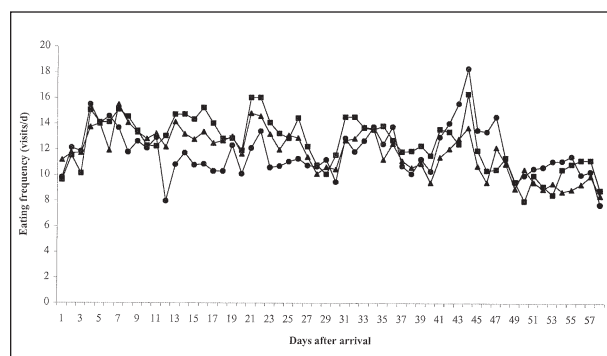


Figure 2—Eating frequency of calves that were sick (circles), not sick (squares), and not removed (triangles) from their pen. Frequency was defined as the presence of a calf at the feedbunk for ≥ 5.25 seconds. A new event was recorded when the calf left the feedbunk for ≥ 300 seconds and subsequently returned.

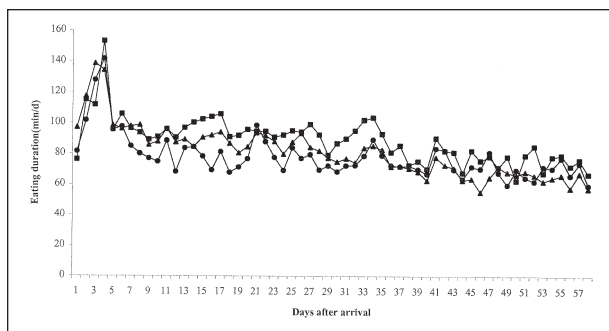


Figure 3—Eating duration for calves that were sick, not sick, and not removed from their pen. See Figure 2 for key.

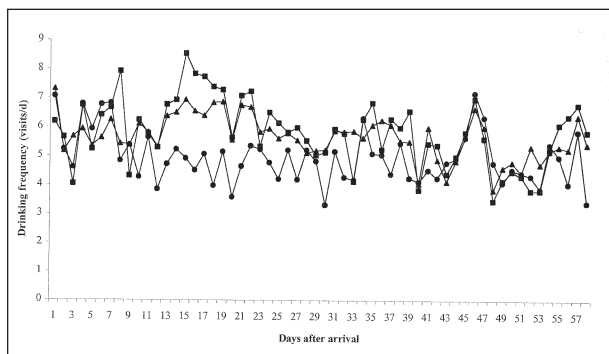


Figure 4—Drinking frequency for calves that were sick, not sick, and not removed from their pen. Frequency was defined as the presence of a calf at the waterer for ≥ 5.25 seconds. A new event was recorded when the calf left the waterer for ≥ 300 seconds and subsequently returned. See Figure 2 for key.

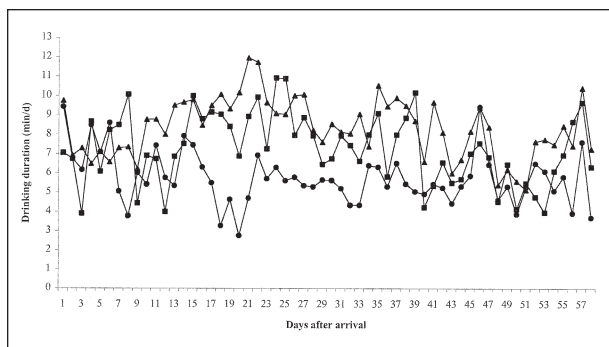


Figure 5—Drinking duration for calves that were sick, not sick, and not removed from their pen. See Figure 2 for key.

pulmonary tissue involved with pneumonic lesions had significantly lower frequency and duration of eat-

Table 1—Least-squares means (\pm SEM) for eating and drinking behaviors of newly arrived calves at a feedlot that were sick, removed but not sick, or not removed

Days after arrival	Eating frequency (visits*/d)		Eating duration (min/d)		Drinking frequency (visits*/d)		Drinking duration (min/d)	
	Sick	Not removed or not sick	Sick	Not removed or not sick	Sick	Not removed or not sick	Sick	Not removed or not sick
1-3	11.03(0.64)	11.40(0.26)	103.29(8.49)	115.29(3.45)	5.52(0.49)	5.98(0.20)	7.51(1.13)	7.72(0.46)
4-5	14.33(0.80)	13.88(0.31)	113.71(7.76)	116.21(2.96)	6.16(0.46)†	5.67(0.18)†	7.59(1.04)†	6.79(0.40)†
6-10	11.77(0.74)	13.82(0.29)	75.17(5.98)	93.15(2.39)	5.28(0.41)	5.87(0.16)	5.26(0.97)	7.40(0.39)
11-27	10.20(0.61)†	13.18(0.23)†	70.55(5.59)†	89.67(2.12)†	4.16(0.37)†	6.32(0.14)†	5.12(1.29)†	9.58(0.49)†
28-57	11.94(0.58)†	11.11(0.21)†	67.74(4.86)	71.60(1.75)	4.71(0.31)	5.42(0.11)	5.06(1.00)	7.92(0.36)

*Defined as the presence of a calf at the feedbunk (eating) or waterer (drinking) for ≥ 5.25 seconds. A new event was recorded when the calf left the feedbunk or waterer for ≥ 300 seconds and subsequently returned. †Logistic regression revealed an association ($P \leq 0.05$) between sickness status and behaviors.

ing 11 to 27 days after arrival but had a significantly higher frequency and duration of eating 28 to 57 days after arrival. Analysis of regression coefficients revealed a significant association between percentage of pulmonary tissue affected at slaughter and eating behavior for specific time periods (regression coefficient for eating frequency on days 11 to 27 and 28 to 57, -3.26 and 3.42 , respectively [$R^2 = 0.1254$]; regression coefficient for eating duration on days 11 to 27 and 28 to 57, -0.336 and 0.279 , respectively [$R^2 = 0.0687$]).

Mean (\pm SEM) daily gain for the study period (days 0 to 57 or 62) for sick calves was 1.16 ± 0.19 kg, whereas calves not removed or that were not sick had a significantly ($P \leq 0.01$) higher MDG of 1.63 ± 0.06 kg. The MDG for the entire feeding period for sick calves (1.21 ± 0.12 kg) was significantly less than that for calves that were not removed or not sick (1.32 ± 0.04 kg).

Agreement beyond chance for being sick and having severe pulmonary lesions at slaughter was adequate ($\kappa = 0.44$). Sixteen of 22 (72.7%) calves that were sick had severe pulmonary lesions at slaughter, whereas 21 of 124 (16.9%) calves that were not removed or not sick had severe pulmonary lesions at slaughter. However, agreement beyond chance between all removed calves and any degree of pulmonary lesions (minor or severe) at slaughter was low ($\kappa = 0.08$). Thirty-seven of 38 (97.4%) calves that were removed had minor or severe pulmonary lesions at slaughter, whereas 90 of 108 (83.3%) calves that were not removed had minor or severe pulmonary lesions at slaughter.

The McNemar χ^2 test indicated a significantly ($P \leq 0.01$) greater-than-expected number of calves that were classified as not sick had severe pulmonary lesions at slaughter. In addition, results of the McNemar χ^2 test indicated a significantly ($P \leq 0.01$) greater-than-expected number of calves that were not removed had minor or severe pulmonary lesions at slaughter.

Discussion

The distribution of respiratory tract disease over time (Fig 1) indicated that 39 of 43 (91.7%) of the calves removed in the initial 57 days after arrival were removed on or before day 27. Visual and statistical examinations of the data revealed that sick calves had significantly lower values for eating and drinking 11 to 27 days after arrival. Sowell et al.^{3,4} reached a similar conclusion, stating that treated calves did not eat as aggressively as untreated calves. The SEM for frequen-

cy and duration of eating and drinking were lower, but not significantly, for calves that were not sick and not removed, compared with values for sick calves.

At slaughter, 3.26 and 0.34% decreases in percentage of pulmonary tissue affected were associated with a 1-increment increase in frequency of eating and duration of eating, respectively, 11 to 27 days after arrival. Although classification at slaughter lacks the ability to determine whether these lesions developed during the initial 57 days, historical patterns for morbidity and mortality attributable to BRDC support the fact that some, if not most, of these lesions develop or are exacerbated during the early part of the feedlot period. Percentage of pulmonary lesions for calves that died was included in analysis of pulmonary lesions. Calves with minor or no pulmonary lesions at slaughter ate more often and for a longer duration 11 to 27 days after arrival than cattle with severe pulmonary lesions. Lower frequency and duration of eating for calves with severe pulmonary lesions may be associated with sickness, removal status, treatment, or a combination of these factors before or during 11 to 27 days after arrival. Calves with severe pulmonary lesions at slaughter ate significantly more often and for a longer duration 28 to 57 days after arrival. Greater values for eating behavior of calves with severe pulmonary lesions may be associated with a postsickness compensatory phenomenon, a higher maintenance requirement, or a slower rate of feed consumption.

Sick calves had a significantly greater frequency and duration for drinking 4 to 5 days after arrival (Table 1). The use of drinking behavior 4 to 5 days after arrival may be a useful prognostic indicator of BRDC. There is an epidemiologic advantage for the use of the period 4 to 5 days after arrival for the prediction of BRDC, because use of the period 11 to 27 days after arrival results in retrospective classification of many of the calves.

The MDG was significantly lower for sick calves, compared with calves not sick and not removed. Analysis of these data suggests that sick calves had a lower 57- or 62-day MDG and that lower growth performance continued throughout the period in the feedlot.

Data were corrected for any situation that resulted in a loss of behaviors regarding eating or drinking for specific calves or all calves in the pen for a period of ≥ 2 hours. This corrected the data for calves that were missing from their pen as a result of treatment, chronic sickness, straying, or death; it also accounted for system failures, which may have resulted in artificially lowered scores for behaviors of calves that had been removed.

Prevalence of pulmonary lesions in this study was 87% (127/146). Degree of diagnostic agreement ($\kappa = 0.44$) between sick calves and calves with severe pulmonary lesions at slaughter was adequate. The κ value describes the proportion of the maximum achievable degree of agreement after adjusting for chance. The high positive-predictive value indicated that sick calves would have severe pulmonary lesions at slaughter. The high negative-predictive value indicated that calves that were not sick or not removed would have minor or no pulmonary lesions at slaughter.

Analysis of results indicated the degree of diagnostic agreement ($\kappa = 0.08$) between calves that were removed for BRDC and calves with minor or severe pulmonary lesions at slaughter was low. The high positive-predictive value indicates removed calves would have pulmonary lesions at slaughter, which is partially a result of the high prevalence of pulmonary lesions. The low negative-predictive value indicates calves not removed also would have pulmonary lesions at slaughter. The disparity of agreement between removal status and pulmonary lesions is similar to findings by Wittum et al,⁹ who reported that 22% of treated steers did not have lesions evident at slaughter and 70% of untreated steers had lesions evident at slaughter.

Low negative-predictive values for sickness status versus percentage of pulmonary lesions and removal status versus percentage of pulmonary lesions were substantiated by the use of a χ^2 test. Results of the test confirmed the pattern of false results is not what would be expected as a result of chance. The large number of false-negative results indicated errors were made toward not removing cattle for treatment that had pulmonary lesions. However, the small number of false-positive results indicated that calves that do not have pulmonary lesions at slaughter are not identified as having respiratory tract disease during the period in a feedlot.

Data regarding removal, sickness status, and pulmonary lesions were analyzed. Of 38 cattle that were removed and for which lungs were available, 37 had pulmonary lesions evident at slaughter, and 19 (51%) of these were classified as severe pulmonary lesions. Of 43 removed calves, 16 (38%) had rectal temperatures at time of first removal of ≥ 40.0 C, including 1 calf that did not have pulmonary lesions evident at slaughter. Twenty-three (53%) of the removed calves were classified as sick at time of initial removal, determined on the basis of the retrospective sickness scoring system, including 1 calf that did not have pulmonary lesions evident at slaughter.

The period during which these pulmonary lesions developed is unclear. It is plausible that some calves arrived at the feedlot with pulmonary lesions. A substantial number of pulmonary lesions may have been developing during the 57- or 62-day eating period, as determined on the basis of the moderate to high risk of developing BRDC, removal rate, sickness rate, and mortality rate.

Current methods for identifying cattle with BRDC in feedlots are less than 100% accurate. Physical examination, laboratory tests, and the retrospective scoring system used in the study reported here explored alternative methods for assessing health status of calves. The retrospective scoring system is not intended to measure the severity of clinical respiratory tract disease in feedlot calves. This procedure simply requires detection of multiple clinical signs of BRDC that are readily observable or measurable during physical examination before a calf is considered to be sick. As a result, the probability is reduced that an incorrect diagnosis of BRDC will be made. Additional research will be required to determine the results of those physical examination and laboratory tests that, short of eutha-

natizing the calf and examining the lungs, are most useful for correct classification of BRDC status of calves.

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- ^aGrowSafe System, Airdrie, AB, Canada.
^bTandem 3KL, Rhone Merieux, Athens, Ga.
^cTSV-2, Pfizer, Exton, Pa.
^dOne Shot, Pfizer, Exton, Pa.
^eAlpha-7, Bio-Ceutic Division, Boehringer Ingelheim Animal Health, St Joseph, Mo.
^fMicotil 300 Injection, Elanco Animal Health, Indianapolis, Ind.
^gDectomax, Pfizer, Exton, Pa.
^hAnipro, Anipro, Greeley, Colo.
ⁱSynovex H, Fort Dodge Animal Health, Overland Park, Kan.
^jHeritage 1, Bayer Corp, Shawnee Mission, Kan.
^kVision 7 with Spur, Bayer Corp, Shawnee Mission, Kan.
^lRalgro, Schering-Plough Animal Health Corporation, Union, NJ.
^mBecton-Dickinson Vacutainer, Serum tube No. 366430, Becton-Dickinson, Franklin Lakes, NJ.
ⁿBecton-Dickinson Vacutainer, Whole blood tube No. 366457, Becton-Dickinson, Franklin Lakes, NJ.
^oAbbott Spectrum Series II, Abbott Laboratories, Abbott Park, Ill.
^pBecton-Dickinson Unopette Microcollection System for WBC determination for manual methods, Becton-Dickinson, Franklin Lakes, NJ.
^qFisher Diagnostic Leukostat, Fisher Scientific, Pittsburgh, Pa.
^rFisherbrand Heparinized Microhematocrit Capillary Tube, Fisher Scientific, Pittsburgh, Pa.
^sInternational Equipment Company Micro-Capillary Reader, International Equipment Co, Needham Heights, Mass.
^tSAS/STAT Software, Version 6.12, SAS Institute Inc, Cary, NC.
^uEpiInfoVersion 6, Centers for Disease Control and Prevention, Atlanta, Ga.
^vComputer Programs for Epidemiologic Analysis (PEPI), Version 2.07a, www.usd-inc.com/pepi.html, Nov. 2, 1998.
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