PEER REVIEWED

Case study: Effects of undifferentiated bovine respiratory disease on performance and marbling deposition in feedlot steers fed to a common yield grade endpoint

Daniel U. Thomson[1], *DVM, PhD;* **Eric S. Moore**[1], *DVM;* **Brad J. White**[1], *DVM, MS;* **Chris D. Reinhardt**[2], *PhD*
[1]*Department of Clinical Sciences, Kansas State University, College of Veterinary Medicine, Manhattan, KS 66506*
[2]*Department of Animal Sciences, Kansas State University, Manhattan, KS 66506*
Corresponding author: Dr. Dan Thomson, dthomson@vet.k-state.edu; phone: 785-532-4254; fax: 785-532-5681

Abstract

A total of 202 Angus steers with an average body weight (BW) of 678 ± 73 lb (308 ± 33.2 kg) were used to evaluate the effects of undifferentiated bovine respiratory disease (BRD) on feedlot performance and carcass quality in cattle marketed at a common yield grade endpoint. Calves were fed in a single pen in a commercial feedyard. Individual weights were collected on arrival, at 75 days on feed, and immediately prior to shipment at time of harvest. Cattle were harvested in three different groups based on day 75 BW and ultrasound evaluation: 122, 156, or 178 days on feed. Cattle treated two or more times weighed less upon feedlot arrival, had greater mortality, lower average daily gain (ADG), lower day 75 BW, and less external fat deposition on day 75 than cattle not requiring treatment for BRD ($P < 0.05$). Overall ADG was lower for cattle requiring either one or two or more treatments compared to cattle requiring no treatments; however, ADG from day 75 through harvest was similar among cattle requiring zero, one, and two or more treatments. There was no effect of BRD treatment on hot carcass weight, carcass quality, or yield grade ($P > 0.05$). Lengthening the feeding period to attain a comparable body composition for cattle that were treated for BRD, compared to cattle never treated for BRD, resulted in similar quality grades.

Key words: feedlot, BRD, ADG, marbeling, yield grade

Résumé

Des bouvillons Angus (n = 202, poids corporel moyen 678 ± 73 lbs ou 308 ± 33.2 kg) ont été utilisés afin d'évaluer l'effet des maladies respiratoires bovines non-différenciées sur la performance en parc d'engraissement et sur la qualité de la carcasse chez des bovins mis en marché en atteignant un grade de rendement habituel. Les veaux ont été nourris dans un seul enclos dans un parc d'engraissement commercial. Les poids individuels étaient mesurés à l'arrivée, après 75 jours d'engraissement et juste avant le départ au moment de l'abattage. Le bétail a été abattu dans trois groupes différents selon leur poids au jour 75 et leur évaluation à l'échographie : après 122, 156 ou 178 jours en engraissement. Les animaux traités deux fois ou plus étaient moins gros à leur arrivée au parc d'engraissement, avaient une plus grande mortalité, un gain moyen quotidien (GMQ) moins élevé, un poids corporel moins élevé au jour 75 et moins de dépôt externe de gras au jour 75 que les animaux qui n'étaient pas traités pour des maladies respiratoires bovines ($P < 0.05$). Dans son ensemble, le GMQ était moins élevé chez les animaux qui nécessitaient un traitement ou deux ou plus par rapport à ceux qui n'étaient pas traités. Toutefois, le GMQ du jour 75 à l'abattage était similaire peu importe le nombre de traitements (0, 1, 2 ou plus que deux). Il n'y avait pas d'effet du traitement pour les maladies respiratoires bovines sur le poids de la carcasse chaude, la qualité de la carcasse ou le grade de rendement ($P > 0.05$). Donc, le fait d'allonger la période d'engraissement pour atteindre une composition corporelle comparable chez le bétail traité pour les maladies respiratoires bovines et le bétail non-traité fera en sorte que le grade de rendement sera similaire.

Introduction

The bovine respiratory disease (BRD) complex is costly to the beef industry: death loss from BRD was estimated to cost the feedlot industry $500 million in 1996.[3,14] In 2003, BRD was estimated to cause 67% of total mortalities in the feedlot.[9] Treatment for BRD is associated with decreased feedlot performance and carcass quality,[5,8,14] therefore BRD increases the cost of beef production by decreasing productivity while increasing treatment and death loss costs.[4,7,10]

Carcass quality is extremely important for producers who market their livestock in a system which rewards valuable carcass traits. Marketing grids are typically based on both yield grade and quality grade, with the less desirable carcasses receiving heavy discounts. Discounts for poor quality carcasses tend to be greater per unit of carcass weight than premiums for high quality carcasses for cattle marketed in quality grade and yield grade grids.[17] Ultrasound technology can determine not only subcutaneous fat, but also intramuscular fat content of the live animal, and estimate the optimum marketing window of cattle for increased production efficiency and minimizing carcass discounts, regardless of whether the marketing goal is carcass quality or carcass leanness.[1,2] Measuring the effects of BRD on carcass quality and feedlot performance could be beneficial in determining when to market cattle with high morbidity rates during the finishing phase.

This retrospective case study was designed to examine the effects of BRD on feedlot performance and carcass characteristics of finishing beef cattle.

Materials and Methods

A total of 202 Angus steers with an average body weight (BW) of 678 ± 73 lb (308 ± 33.2 kg) were used to evaluate the effects of BRD on feedlot performance and carcass quality in cattle marketed at a common yield grade endpoint. While weight of the calves ranged from 400 to 900 lb (182 to 409 kg), most calves weighed between 601 and 750 lb (273 and 341 kg; Figure 1). Calves were fed in a single pen in a central Kansas commercial feedyard. Upon feedlot arrival, the calves were vaccinated with a five-way viral vaccine[a] (bovine viral diarrhea virus types 1 and 2, infectious bovine rhinotracheitis virus, bovine respiratory syncytial virus, and parainfluenza-3 virus), and a seven-way clostridial bacterin-toxoid[b] (*Clostridium perfringens* types C and D, *C. chauvoei*, *C. novyi*, *C. sordelli*, and *C. septicum*), treated with an avermectin class pour-on internal and external parasiticide, and given a growth promoting implant. The vaccination history and post-weaning backgrounding program of these

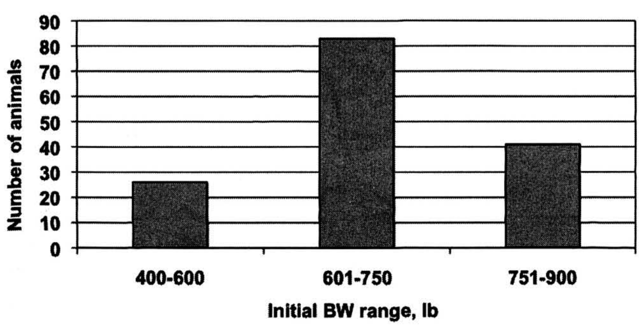

Figure 1. Distribution of cattle by initial body weight (BW) upon arrival in a pen of cattle in a commercial feedlot.

calves allowed them to be classified as low-risk cattle, and therefore were not administered a metaphylactic antimicrobial treatment upon arrival. All cattle were tracked during the feeding and slaughter phases using electronic identification tags.

The cattle were fed a diet consisting of 70% steam-flaked corn, 12% distillers grains, 2.7% fat, 4.4% hay, 2.1% silage, 3.0% corn screenings, and 5.3% liquid protein supplement (dry matter basis). Feed was delivered twice daily (am and pm). Cattle were housed in a single open air, dirt floor pen. The pen allowed nose-to-nose contact only with cattle in an adjacent pen on one side of their home pen.

Individual body weights were collected on arrival, at 75 days on feed (DOF), and immediately prior to shipment at time of harvest; day 75 and pre-harvest weights were shrunk 4%. Individual average daily gain (ADG) was calculated for three periods: 1) arrival to carcass ultrasound (75 DOF); 2) ultrasound to harvest; and 3) the entire feeding period.

Percents of intramuscular fat (IMF) and backfat (BF) thickness were determined using ultrasound measurements at 75 DOF. The cattle were harvested in three different harvest groups: 122, 156, and 178 DOF, based on BW and ultrasound evaluation taken on day 75. Following harvest, hot carcass weight (HCW), marbling score, quality grade, ribeye area (REA), fat thickness (FT), and yield grade estimated by USDA personnel were reported by the slaughter facility for each individual carcass.

Health information was evaluated daily by trained health professionals employed by the feedyard. Date of BRD treatment, rectal temperature, BW, treatment code, and products administered were recorded. Criteria for diagnosis of BRD and protocols for subsequent therapy were predetermined by the consulting veterinarian and administered by feedlot personnel. Cattle were only considered "treated" if they were removed from the home pen (pulled) based on clinical signs observed by feedlot health personnel, and recorded a rectal temperature of 103.5°F (39.7°C) or greater. If cattle were removed from the home pen based on clinical signs of BRD but did not have a qualifying rectal temperature, they were classified as "respiratory-observe" and were not treated with an antimicrobial. However, if cattle classified previously as respiratory-observe were subsequently identified with signs of BRD, they were then counted as being pulled for first and second treatments.

Cattle that qualified for initial treatment of BRD were treated with florfenicol[c] subcutaneously at 6 mL/100 lb of BW (18.2 mg/lb or 40 mg/kg of BW) if clinical signs were severe, or oxytetracycline[d] subcutaneously at 5 mL/100 lb BW (10 mg/lb or 22 mg/kg BW) if clinical signs were mild. Cattle classified as respiratory-observe were not treated with an antimicrobial.

Statistical analysis was done with version 9.3 of SAS.[e] Continuous variables were analyzed using the MIXED procedure and categorical variables were analyzed using the GLIMMIX procedure. Initial BW was used as a covariate for analysis of the effects of number of times treated for BRD, but no covariable was used for analysis of effects of harvest group. The independent variables were number of treatments for BRD and harvest group. Dependent variables that were analyzed included: arrival BW, BW at 75 DOF, IMF (measured using ultrasound) at 75 DOF, BF (measured using ultrasound) at 75 DOF, ADG from 0 through 75 DOF, HCW, marbling score (post-slaughter as evaluated by USDA personnel), REA and FT post-harvest, yield grade, BW at shipment to harvest, ADG from 75 DOF through harvest and over the entire feeding period, and mortality percentage. Means were considered different with a protected F-test < 0.05. Orthogonal linear and quadratic contrast statements were included for number of treatments for BRD and harvest group; by convention, if more than one different order effects (linear, quadratic, polynomial) are significant ($P < 0.05$), the higher order effect (in this case quadratic) is considered the most relevant. There were no significant interactions ($P > 0.10$) between number of treatments and harvest group. Therefore, only the main effects of number of treatments and harvest group are reported.

Results and Discussion

Sixty-six percent of the cattle were treated for signs of BRD at some point during the feeding period. Temporal patterns of pull rates are illustrated in Figure 2. The first calf was pulled for BRD treatment at 15 DOF, and there was a spike in BRD morbidity between 21 and 26 DOF. This is noteworthy because these calves originated from a single ranch, and had been vaccinated on the ranch prior to shipment to the feedlot.[10] However, this is consistent with post-feedlot arrival morbidity patterns of single-source, ranch-fresh calves as compared to commingled or auction-derived calves. Step *et al*[15] reported that the average number of DOF at first treatment in single-source, ranch-fresh calves was more than double that for commingled, auction-derived calves.

A total of 33% of the cattle were never treated for BRD, 51% were treated once, and 15% were treated two or more times. The majority of cattle that required treatment for BRD were pulled by four weeks on feed. Cattle treated once averaged 28 DOF at initial treatment, while cattle treated two or more times averaged 24 DOF at initial treatment ($P < 0.05$). No cattle were pulled for BRD after 75 DOF.

Initial BW was numerically lower for calves treated two or more times compared to those not treated ($P = 0.20$; Table 1). Reinhardt *et al*[12] reported a linear decrease in initial BW with increasing number of treatments for morbidity; however, Gardner *et al*[5] reported no relationship between initial BW and morbidity. At 75 DOF BW and ADG showed a linear decrease with number of times treated for BRD ($P < 0.01$). This agrees with earlier studies[5,6,12] which reported a reduction in ADG in cattle treated for BRD compared to non-treated cattle. Schneider *et al*[13] reported that treatment for BRD reduced ADG both in the early feeding period and the entire feeding period. Mortality also increased in a linear fashion with increasing number of respiratory treatments ($P < 0.01$), in agreement with Reinhardt *et al.*[12]

Based on ultrasound measurements, FT at 75 DOF decreased as the number of treatments for BRD increased ($P = 0.03$; Table 1), and there was less IMF at 75 DOF in calves treated two or more times compared to calves treated only once; IMF in non-treated calves did not differ from either calves treated once or those treated greater than once ($P < 0.05$). Holland *et al*[6] also showed a negative relationship between number of times treated for BRD and IMF and FT measured at 65 DOF. That study also showed a linear reduction in dry matter intake with increasing number of treatments for BRD, which suggests reduced energy available for storage, either as marbling or external fat.

Although treatment for BRD reduced ADG prior to day 75, daily gain from day 75 through harvest did not differ among number of times treated for BRD ($P \geq 0.31$; Table 2). However, because of lower ADG in treated calves early in the feeding period, gain in the overall finishing phase was lower for calves treated for BRD compared to non-treated calves (linear, $P < 0.01$), and DOF tended (linear, $P = 0.07$) to be greater for calves treated more than once compared to non-treated calves. Reduced ADG in treated calves is supported by results reported by Reinhardt *et al*[12] and Schneider *et al.*[13] Also,

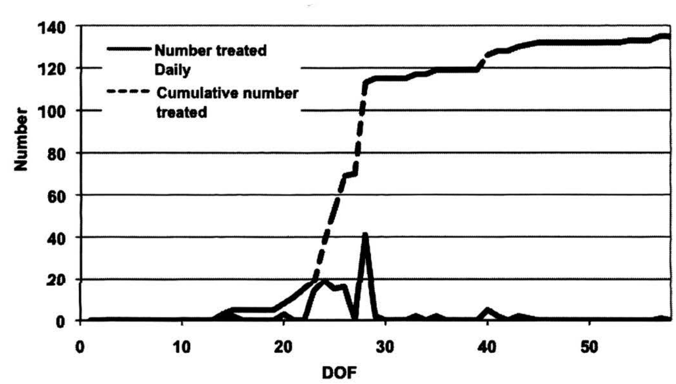

Figure 2. Days on feed (DOF) when cattle were first removed from the pen for respiratory treatment or observation, and cumulative number of cattle removed for BRD treatment/observation.

Table 1. Performance (through 75 DOF) and fatness for Angus steers treated 0, 1, or ≥ 2 times for BRD in a Kansas feedlot.

	Number of treatments for BRD				*P*-value	
	0	1	≥ 2	SEM[1]	Linear	Quadratic
Number of calves	68	103	31			
Initial BW, lb	686	702	671	16.9	0.46	0.07
Mortality, %	1.5[a]	2.1[a]	12.5[b]	6.12	< 0.01	0.07
BW d 75, lb	999[a]	948[b]	926[b]	18.7	< 0.01	0.40
ADG d 0 through d 75, lb/d	4.05[a]	3.66[b]	3.08[b]	0.244	< 0.01	0.40
IMF[2] on d 75,[3] %	4.9[ab]	5.0[a]	4.8[b]	0.08	0.28	< 0.01
FT on d 75,[3] inch	0.28[a]	0.26[ab]	0.23[b]	0.017	0.03	0.89

[1]Largest standard error of the three groups
[2]Intramuscular fat (IMF)
[3]Fat thickness (FT) measured by ultrasound
[a,b]Means within a column without a common superscript differ ($P < 0.05$)

Table 2. Post-ultrasound (75 DOF) performance and carcass traits of Angus steers treated 0, 1, or ≥ 2 times for BRD fed in a Kansas feedlot.

	Number of treatments for BRD				*P*-value	
	0	1	≥ 2	SEM[1]	Linear	Quadratic
Number of calves	62	93	26			
Days on feed	157	162	168	4.5	0.07	0.78
Live BW at harvest, lb	1318	1296	1274	27.1	0.11	0.90
ADG from 75 DOF to harvest, lb/d	3.89	3.94	3.78	0.242	0.44	0.31
ADG harvest, lb/d	3.94[a]	3.70[b]	3.48[b]	0.141	< 0.01	0.86
Hot carcass weight, lb	832	821	810	18.0	0.20	0.90
Marbling score	548	562	541	19.1	0.76	0.24
Quality grade	5.16	5.24	5.23	0.192	0.75	0.74
Prime and Choice, %	65	74	72	8.8	0.48	0.42
Ribeye area, sq inch	13.86	13.47	13.55	0.273	0.35	0.30
Fat thickness, inch	0.63[a]	0.57[b]	0.53[b]	0.033	0.02	0.65
Yield grade (YG), calculated	3.32	3.23	3.07	0.147	0.14	0.74
YG, USDA	2.93	2.89	2.89	0.134	0.84	0.88
YG 1+2, %	31	24	20	8.9	0.40	0.85
YG 3, %	49	64	72	9.8	0.19	0.42
YG 4+5, %	20	12	8	7.1	0.13	0.76

[1]Largest standard error of the three groups
[a,b]Means within a column without a common superscript differ ($P < 0.05$)

Pinchak *et al*[11] noted that the negative effect of BRD on ADG was proportional to the duration of observed BRD. Interestingly, BW at harvest did not differ by number of respiratory treatments. Holland *et al*[6] also showed that ADG after 65 DOF was not affected by the number of times treated for respiratory disease prior to day 65, and they also reported that overall ADG, when performance prior to day 65 was included, was adversely affected by BRD. Thompson *et al*[16] reported that treatment for respiratory disease was associated with reduced performance prior to 35 DOF and during the overall feeding period, but ADG from day 35 through harvest was not affected by treatment for BRD prior to day 35.

Treatment for BRD did not significantly affect final BW or HCW, but there was a tendency for a lower final BW (linear, $P = 0.11$) with increasing number of BRD treatments. Cattle treated for BRD had decreased FT at slaughter (linear, $P = 0.02$), while calculated yield grade (linear, $P = 0.14$) and percentage of cattle with yield grade 4 and 5 (linear, $P = 0.13$) tended to decrease with increasing number of BRD treatments.

The design of the study was to market cattle at or near the same yield grade endpoint based on ultrasound values and BW measured on day 75.[18] Although FT at harvest was different between non-treated and treated cattle (0.63 vs 0.57 and 0.53 inch or 1.60 vs 1.45 and 1.35 cm for non-treated vs calves treated once and at least two times, respectively; $P < 0.05$), yield grade, marbling score, quality grade, percentage USDA Prime and Choice, and REA did not differ ($P \geq 0.30$) based on number of treatments for respiratory disease. Conversely, Reinhardt *et al*[12] and Schneider *et al*[13] showed a decrease in marbling score and quality grade with increased number of treatments for feedlot morbidity, even though the cattle in these datasets were sorted into groups prior to marketing based on visual appraisal of finish. In those two studies, despite attempts to market cattle only after achieving a uniform level of fatness, cattle treated for BRD had lower FT than non-treated cattle. Gardner *et al*[5] showed a numerical decrease in marbling score with increasing number of treatments for BRD and a significant reduction in marbling score in cattle with lung lesions resulting from earlier BRD. However, those studies did not intentionally provide treated cattle additional DOF to achieve an external fat-constant endpoint; to the contrary, both studies reported a linear decrease in yield grade and FT with increasing treatments for morbidity. In the present study, morbidity affected animal performance early in the feeding period, but did not affect the animals' ability to deposit marbling if allowed to reach a similar degree of finish compared to non-treated cattle.

Cattle were harvested in three different groups using BW, BF, and IMF percent at 75 DOF to estimate days to reach yield grade 3. Initial BW was not different between harvest groups (Table 3). Daily gain, BW, IMF, and FT at day 75 decreased linearly ($P < 0.01$) with increasing DOF, by design. Number of treatments for BRD was not different between cattle in harvest groups 1 and 2, but was greater for those cattle assigned to harvest group 3 (1.1 treatment per animal) than cattle in harvest groups 1 (0.6 treatments per animal) and 2 (0.7 treatments per animal; quadratic, $P = 0.01$), which may be reflected in the linear decrease in BW, ADG, IMF, and BF measurements at day 75 (Table 3).

Average daily gain from day 75 through harvest did not differ by harvest group (Table 4), and the assignment of harvest group based on ultrasound was more accurate for groups 2 and 3 compared to group 1; group 1 had lighter BW and HCW but also lower yield grade, marbling score, and percentage Prime and Choice carcasses compared to groups 2 and 3, indicating that calves in group 1 could have been fed for additional days to attain a greater fat content endpoint.

The percentage of cattle never treated for BRD was lower in harvest group 3 compared to harvest groups 1 and 2 (quadratic, $P < 0.01$; Table 5), and the percentage of cattle harvested in the later harvest groups (2 or 3) increased linearly ($P < 0.01$; Table 6) with increasing number of treatments for BRD. Holland *et al*[6] reported that cattle treated three times for BRD and classified as chronic (those which did not completely respond to antimicrobial therapy) required greater DOF to reach the target fat constant endpoint.

Table 3. Pre-ultrasound performance and ultrasound measures of Angus steers marketed in the first, second, or third harvest group from a pen in a Kansas feedlot.

	Number of harvest group				*P*-value	
	1	2	3	SEM[1]	Linear	Quadratic
Number of calves	33	48	109			
DOF	122	156	178			
Initial body weight (BW), lb	702	697	686	15.4	0.36	0.90
Number of treatments per animal	0.7[a]	0.6[a]	1.1[b]	0.14	0.25	0.01
BW at 75 DOF, lb	1001[a]	992[a]	933[b]	16.3	< 0.01	0.14
ADG at 75 DOF, lb/d	4.07[a]	3.94[a]	3.17[b]	0.213	< 0.01	0.14
IMF[2], % on d 75[3]	5.09[a]	5.01[a]	4.85[b]	0.04	< 0.01	0.64
FT, inch on d 75[3]	0.38[a]	0.30[b]	0.20[c]	0.007	< 0.01	0.29

[1]Largest standard error of the three groups
[2]Intramuscular fat (IMF)
[3]Fat thickness (FT) measured by ultrasound
[a,b]Means within a column without a common superscript differ ($P < 0.05$).

Table 4. Post-ultrasound (75 DOF) performance and carcass traits measured at harvest for Angus steers marketed in the first, second, or third harvest group from a pen in a Kansas feedlot.

	Number of harvest group				*P*-value	
	1	2	3	SEM[1]	Linear	Quadratic
Number of calves	33	47	100			
Live BW at harvest, lb	1175[a]	1324[b]	1338[b]	20.7	< 0.01	< 0.01
ADG 75 DOF to harvest, lb/d	3.72	4.03	3.94	0.143	0.18	0.17
ADG arrival through harvest, lb/d	3.87[ab]	3.89[a]	3.63[b]	0.117	0.09	0.22
HCW, lb	728[a]	832[b]	854[b]	13.2	< 0.01	< 0.01
Marbling score	502[a]	558[b]	569[b]	16.3	< 0.01	0.19
Quality grade	4.84	5.29	5.29	0.17	< 0.01	0.19
Prime and Choice, %	54[a]	77[b]	73[b]	7.8	0.03	0.09
Ribeye area, sq inch	13.49	13.55	13.69	0.237	0.47	0.88
Fat thickness, inch	0.55[a]	0.66[b]	0.56[a]	0.286	0.58	< 0.01
Yield grade (YG), calculated	2.78[a]	3.49[b]	3.28[b]	0.121	< 0.01	< 0.01
YG, USDA	2.48[a]	2.96[b]	3.01[b]	0.109	< 0.01	0.06
YG 1+2, %	52[a]	19[b]	18[b]	7.2	< 0.01	0.03
YG 3, %	48	69	62	8.5	0.23	0.10
YG 4+5, %	0	12	20	6.1	< 0.01	0.70

[1]Largest standard error of the three groups
[a,b]Means within a column without a common superscript differ ($P < 0.05$).

Table 5. Percentage of Angus steers marketed in the first, second, or third harvest group which were treated either 0, 1, or ≥ 2 times for BRD from a pen in a Kansas feedlot.

	Number of harvest group				*P*-value	
	1	2	3	SEM[1]	Linear	Quadratic
Number of calves	33	48	109			
Number of treatments:						
0, % of harvest group	37[a]	54[a]	24[b]	8.0	0.14	< 0.01
1, % of harvest group	54	39	57	8.6	0.72	0.07
≥ 2, % of harvest group	9	7	19	6.0	0.21	0.22

[1]Largest standard error of the three groups
[a,b]Means within a column without a common superscript differ ($P < 0.05$).

Table 6. Percentage of Angus steers treated 0, 1, or ≥ 2 times for BRD which were marketed in the first, second, or third harvest group from a pen in a Kansas feedlot.

	Number of treatments				*P*-value	
	0	1	≥ 2	SEM[1]	Linear	Quadratic
Number of calves	62	93	26			
Harvest group:						
1, %	19	18	12	7.4	0.39	0.59
2, %	41[a]	19[b]	12[b]	8.2	0.01	0.58
3, %	40[a]	63[b]	76[b]	9.3	< 0.01	0.72

[1]Largest standard error of the three groups
[a,b]Means within a column without a common superscript differ ($P < 0.05$).

Conclusions

Undifferentiated BRD reduced ADG and fat deposition in feeder calves early in the feeding period; however, post-recovery ADG was similar to those never treated for BRD. Therefore, lengthening the feeding period to attain a comparable body composition for cattle that were treated for BRD compared to cattle never treated for BRD can result in similar quality grades for treated compared to cattle that were never treated for BRD.

Endnotes

[a]Bovi-Shield GOLD® 5, Pfizer Animal Health, New York, NY
[b]Vision® 7, Merck Animal Health, Whitehouse Station, NJ
[c]Nuflor®, Merck Animal Health, Whitehouse Station, NJ
[d]Liquamycin® LA-200®, Pfizer Animal Health, New York, NY
[e]SAS Institute, Cary, NC

Acknowledgements

Contribution #12-265-J from the Kansas Agricultural Experiment Station, Manhattan, KS 66506. The authors declare no conflict of interest.

References

1. Brethour JR. The relationship of average backfat thickness of feedlot steers to performance and relative efficiency of fat and protein retention. *J Anim Sci* 2004;82:3366-3372.
2. Brethour JR. Using receiver operating characteristic analysis to evaluate the accuracy in predicting future quality grade from ultrasound marbling estimates on beef calves. *J Anim Sci* 2000;78:2263-2268.
3. Brown JF, Leite F, Czuprynski CJ. Binding of *Pasteurella haemolytica* leukotoxin to bovine leukocytes. *Infect Immun* 1997;65:3719-3724.
4. Galyean ML, Perino LJ, Duff GC. Interaction of cattle health/immunity and nutrition. *J Anim Sci* 1999;77:1120-1134.
5. Gardner BA, Dolezal HG, Bryant LK, Owens FN, Smith RA. Health of finishing steers: Effects on performance, carcass traits, and meat tenderness. *J Anim Sci* 1999;77:3168-3175.
6. Holland BP, Burciaga-Robles LO, VanOverbeke DL, Shook JN, Step DL, Richards CJ, Krehbiel CR. Effect of bovine respiratory disease during preconditioning on subsequent feedlot performance, carcass characteristics, and beef attributes. *J Anim Sci* 2010;88:2486-2499.
7. Irsik M, Langemeyer M, Schroeder T, Spire M, Roder JD. Estimating the effects of animal health on the performance of feedlot cattle. *Bov Pract* 2006;40:65-74.
8. Larson RL. Effect of cattle disease on carcass traits. *J Anim Sci* 2005;83:E37-43.
9. Loneragan G. Feedlot mortalities: epidemiology, trends, classification. *Acad Vet Consult* 2004;32:34-43.
10. Macartney JE, Bateman KG, Ribble CS. Health performance of feeder calves sold at conventional auctions versus special auctions of vaccinated or conditioned calves in Ontario. *J Am Vet Med Assoc* 2003;223:677-683.
11. Pinchak WE, Tolleson DR, McCloy M. Morbidity effects on productivity and profitability of stocker cattle grazing in the Southern Plains. *J Anim Sci* 2004;82:2773-2779.
12. Reinhardt CD, Busby WD, Corah LR. Relationship of various incoming cattle traits with feedlot performance and carcass traits. *J Anim Sci* 2009;87:3030-3042.
13. Schneider MJ, Tait Jr RG, Busby WD, Reecy JM. An evaluation of bovine respiratory disease complex in feedlot cattle: Impact on performance and carcass traits using treatment records and lung lesion scores. *J Anim Sci* 2009;87:1821-1827.
14. Smith RA. Impact of disease on feedlot performance: a review. *J Anim Sci* 1998;76:272-274.
15. Step DL, Krehbiel CR, DePra HA, Cranston JJ, Fulton RW, Kirkpatrick JG, Gill DR, Payton ME, Montelongo MA, Confer AW. Effects of commingling beef calves from different sources and weaning protocols during a forty-two-day receiving period on performance and bovine respiratory disease. *J Anim Sci* 2008;86:3146-3158.
16. Thompson PN, Stone A, Schultheiss WA. Use of treatment records and lung lesion scoring to estimate the effect of respiratory disease on growth during early and late finishing periods in South African feedlot cattle. *J Anim Sci* 2006;84:488-498.
17. USDA. National carcass premiums and discounts. USDA Market News Service, St. Joseph, MO, 2003.
18. Wall PB, Rouse GH, Wilson DE, Tait Jr RG, Busby WD. Use of ultrasound to predict body composition changes in steers at 100 and 65 days before slaughter. *J Anim Sci* 2004;82:1621-1629.