An Evaluation of the Metaphylactic Effect of Ceftiofur Crystalline Free Acid in Feedlot Calves*

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CLINICAL RELEVANCE

The relative effect of metaphylactic ceftiofur crystalline free acid (CCFA) versus metaphylactic tilmicosin was evaluated in beef calves under commercial feedlot conditions in Nebraska. At feedlot arrival, 11,605 animals at ultrahigh risk of developing bovine respiratory disease (BRD) were allocated to one of three experimental groups: CCFA-3 (6.6 mg/kg SC), CCFA-7 (6.6 mg/kg SC), or TILM-3 (tilmicosin, 10 mg/kg SC). Animals were eligible for subsequent BRD treatment 3 (CCFA-3 and TILM-3 groups) or 7 (CCFA-7 group) days later. Compared with the TILM-3 group, overall chronicity, overall mortality, BRD mortality, and metabolic mortality rates were significantly (P < .05) lower in the CCFA-3 and CCFA-7 groups; average daily gain was significantly (P < .05) higher in the CCFA-3 group; the proportion of quality grade No Roll carcasses was significantly (P < .05) lower in the CCFA-3 and CCFA-7 groups; and there were per-animal advantages of $22.05 and $18.98 in the CCFA-3 and CCFA-7 groups, respectively. In beef calves at ultrahigh risk of developing BRD, it is more cost effective to administer metaphylactic CCFA than tilmicosin at feedlot arrival.

INTRODUCTION

Undifferentiated fever (UF), also referred to as bovine respiratory disease (BRD) complex or shipping fever, is the single most important health problem in beef feedlot production. The management of this disease complex has become significantly more sophisticated with the administration of prophylactic (preventive)

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or metaphylactic (both preventive and therapeutic) antimicrobials to calves on arrival at the feedlot if they are at high or ultrahigh risk of developing UF/BRD. Studies investigating metaphylactic parenteral oxytetracycline or tilmicosin in feedlot cattle have demonstrated reductions in BRD morbidity rates, BRD mortality rates, and/or overall mortality rates and improvements in average daily gain (ADG) and/or feed efficiency compared with no metaphylaxis. The qualitative determination of the risk of any given population of feedlot animals in commercial production scenarios developing UF/BRD is made based on a number of factors, including age class (calf versus yearling), body weight (often a proxy for age), procurement method (sale barn versus ranch direct), amount of commingling both before and after arrival, and vaccination and management history.

Recently, ceftiofur crystalline free acid (CCFA; Excede Sterile Suspension, Pfizer Animal Health) was approved for the treatment and control of BRD associated with Mannheimia haemolytica, Pasteurella multocida, and Histophilus somni. Based on the pharmacokinetics of CCFA and the comparative efficacy data generated for licensing purposes, it has been hypothesized that CCFA may be more cost effective than other antimicrobials for controlling UF/BRD in populations of feedlot animals that are at a high or ultrahigh risk of developing the disease. Furthermore, based on the pharmacokinetics of CCFA, it has been suggested that the prolonged time during which CCFA levels remain above the minimum inhibitory concentrations for the common bacteria pathogens of UF/BRD in feedlot cattle may allow for minimal animal health detection, diagnosis, and treatment activities for up to 7 to 10 days after arrival, which could result in substantial input cost savings. This approach would be different from the standard industry approach, which commonly involves the detection, diagnosis, and treatment of animals with UF/BRD starting 3 days after arrival. Data describing the relative metaphylactic efficacy of CCFA in commercial feedlot production are limited.

**Undifferentiated fever, also referred to as bovine respiratory disease complex or shipping fever, is the single most important health problem in beef feedlot production.**

The overall purpose of this study was to determine the relative cost effectiveness of metaphylactic CCFA and tilmicosin (Micotel 300 Injection, Elanco Animal Health) when administered on arrival at the feedlot to beef calves at ultrahigh risk of developing UF/BRD. A secondary objective was to determine whether the prolonged duration of elevated CCFA levels allows for minimal UF/BRD detection, diagnosis, and treatment activities during the first 7 days after metaphylactic CCFA administration.

**MATERIALS AND METHODS**

**General Overview**

In this commercial field trial, feedlot calves at ultrahigh risk of developing UF/BRD were randomly allocated at feedlot arrival to one of the three experimental groups. Animals in the same experimental group were housed within the same pen, which was the experimental unit. Study animals were followed from allocation until slaughter, and outcome variables were measured to compare animal health, feed-
lot performance, and carcass characteristics between the groups. Statistical analyses were used to determine the probability of whether differences in outcome variables between the groups were due to the effect of the experimental groups or random chance. Differences in outcome variables that were unlikely to be the result of random chance (\( P < .05 \)) were subsequently incorporated into economic models to determine the relative economic impact of each experimental group.

**Trial Facilities**

The study was conducted at a commercial feedlot located near Broken Bow, Nebraska, with a capacity of approximately 85,000 animals. The basic design of this feedlot is representative of standard designs used in Nebraska. Open-air, dirt-floor pens are arranged side by side with central feed alleys. There are 176 large pens in the feedlot with capacities of 200 to 600 animals/pen; the remaining 102 pens are smaller, with capacities ranging from 60 to 200 animals/pen.

The feedlot has two mobile hospital facilities, one permanent hospital facility, and an enclosed processing facility. Each of these facilities has a hydraulic chute equipped with an individual animal scale, a chute-side computer for animal health data, and separation alleys to facilitate the return of animals to designated pens. In addition, there are seven recovery and “chronic” pens, 17 receiving pens, and several shipping pens at the feedlot.

**Trial Animals**

The animals used in the study were crossbred beef steer and bull calves purchased from auction markets throughout the western and central United States. Animals were transported by truck to the feedlot after assembly at auction markets. The average initial individual animal weight of pens allocated to the study was between 248 kg (546 lb) and 261 kg (575 lb).

On arrival at the feedlot, the animals were moved through a hydraulic chute for a group of procedures known collectively as processing. All animals were ear-tagged (to provide unique, individual animal identification), implanted with a trenbolone acetate and estradiol benzoate growth implant (Synovex Choice, Fort Dodge Animal Health), and given a multivalent clostridial/\( H. somni \) vaccine (Ultrabac 7/Somubac, Pfizer Animal Health). In addition, each animal received an infectious bovine rhinotracheitis virus, parainfluenza-3 virus, bovine viral diarrhea virus, and bovine respiratory syncytial virus combination vaccine (Pyramid 5, Fort Dodge Animal Health), an \( M. haemolytica–P. multocida \) bacterin–toxoid (Pulmo-guard PHM-1, Boehringer Ingelheim Vetmedica), and topical ivermectin (0.5%) at 1.0 ml/10 kg (Ivermectin Pour-On, Durvet). All bulls were castrated.

At an average of approximately 8 to 10 days on feed (DOF) for each pen, all animals in each experimental group were moved through a handling facility for individual rectal temper-
### Equations Used to Calculate Morbidity and Mortality Rates, Ancillary Production Variables, and Feedlot Performance Variables

#### MORBIDITY AND MORTALITY RATES

<table>
<thead>
<tr>
<th>Equation</th>
<th>Formula</th>
</tr>
</thead>
</table>
| Initial UF Treatment Rate                                                                  | \[
|                                                                                             | \text{Initial UF Treatment Rate} = \frac{\text{No. of Animals Initially Treated for UF}}{\text{No. of Animals Allocated}} \times 100\% |
| First UF Relapse Rate                                                                      | \[
|                                                                                             | \text{First UF Relapse Rate} = \frac{\text{No. of First UF Relapses}}{\text{No. of Animals Initially Treated for UF}} \times 100\% |
| Initial NF Treatment Rate                                                                  | \[
|                                                                                             | \text{Initial NF Treatment Rate} = \frac{\text{No. of Animals Initially Treated for NF}}{\text{No. of Animals Allocated}} \times 100\% |
| First NF Relapse Rate                                                                      | \[
|                                                                                             | \text{First NF Relapse Rate} = \frac{\text{No. of First NF relapses}}{\text{No. of Animals Initially Treated for NF}} \times 100\% |
| Overall Chronicity Rate                                                                    | \[
|                                                                                             | \text{Overall Chronicity Rate} = \frac{\text{No. of Animals Designated as Chronic}}{\text{No. of Animals Allocated}} \times 100\% |
| Overall Wastage Rate                                                                       | \[
|                                                                                             | \text{Overall Wastage Rate} = \frac{\text{No. of Animals Designated as Chronic That Did Not Die}}{\text{No. of Animals Allocated}} \times 100\% |
| Overall Mortality Rate                                                                     | \[
|                                                                                             | \text{Overall Mortality Rate} = \frac{\text{No. of Mortalities Due to All Causes}}{\text{No. of Animals Allocated}} \times 100\% |
| BRD Mortality Rate                                                                         | \[
|                                                                                             | \text{BRD Mortality Rate} = \frac{\text{No. of Mortalities Due to BRD}}{\text{No. of Animals Allocated}} \times 100\% |
| Histophilosis\(^a\) Mortality Rate                                                        | \[
|                                                                                             | \text{Histophilosis}\(^a\) Mortality Rate = \frac{\text{No. of Mortalities Due to Histophilosis}}{\text{No. of Animals Allocated}} \times 100\% |
| Metabolic Mortality Rate                                                                   | \[
|                                                                                             | \text{Metabolic Mortality Rate} = \frac{\text{No. of Mortalities Due to Metabolic Disease}}{\text{No. of Animals Allocated}} \times 100\% |
| Arthritis Mortality Rate                                                                   | \[
|                                                                                             | \text{Arthritis Mortality Rate} = \frac{\text{No. of Mortalities Due to Arthritis}}{\text{No. of Animals Allocated}} \times 100\% |
| Miscellaneous Mortality Rate                                                               | \[
|                                                                                             | \text{Miscellaneous Mortality Rate} = \frac{\text{No. of Mortalities Due to Causes Other than BRD, Histophilosis, Metabolic Disease, or Arthritis}}{\text{No. of Animals Allocated}} \times 100\% |
| Relative Risk                                                                              | \[
|                                                                                             | \text{Relative Risk} = \frac{\text{Risk for the CCFA-3 or CCFA-7 Group}}{\text{Risk for the TILM-3 Group}} |

\(^a\)Histophilosis is a disease caused by *Histophilus somni* infection.
Equations Used to Calculate Morbidity and Mortality Rates, Ancillary Production Variables, and Feedlot Performance Variables (cont.)

ANCILLARY PRODUCTION VARIABLES

**Slaughter Weight** = \( \frac{\text{Total Net Slaughter Weight}}{\text{No. of Animals Slaughtered}} \)

**Weight Gain** = Slaughter Weight – Initial Weight

**Carcass Weight** = \( \frac{\text{Total Carcass Weight}}{\text{No. of Carcasses}} \)

**Dressing Percentage** = \( \frac{\text{Total Carcass Weight}}{\text{Total Net Slaughter Weight}} \times 100\% \)

**DOF** = Average Slaughter Date – Average Allocation Date

**DDMI** = \( \frac{\text{Total Dry Matter Fed}^b}{\text{No. of Animal Days}} \)

FEEDLOT PERFORMANCE VARIABLES

**ADG Live Weight Basis** = \( \frac{(\text{Total Net Slaughter Weight} + \text{Total Weight of Animals Shipped for Salvage Slaughter} + \text{Total Weight of Animals That Died} – \text{Total Initial Weight})}{\text{No. of Animal Days}} \)

**ADG Carcass Weight Basis** = \( \frac{[(\text{Total Carcass Weight} + \text{Fixed Dressing Percentage}^c) + \text{Total Weight of Animals Shipped for Salvage Slaughter} + \text{Total Weight of Animals That Died} – \text{Total Initial Weight}]}{\text{No. of Animal Days}} \)

**DM:G Live Weight Basis** = \( \frac{\text{DDMI}}{\text{ADG Live Weight Basis}} \)

**DM:G Carcass Weight Basis** = \( \frac{\text{DDMI}}{\text{ADG Carcass Weight Basis}} \)

\(^b\)100% dry-matter basis.

\(^c\)Fixed dressing percentage = 63.0%.

ADG = average daily gain.

DDMI = daily dry matter intake.

DM:G = dry matter intake:gain ratio.

DOF = days on feed.

NF = no fever.

UF = undifferentiated fever.
nature measurement, antimicrobial therapy with either long-acting intramuscular oxytetracycline (Liquamycin LA-200, Pfizer Animal Health) at 20 mg/kg (animals with rectal temperature <105.0°F) or subcutaneous florfenicol (Nuflor Injectable Solution, Schering-Plough Animal Health) at 40 mg/kg (animals with rectal temperature ≥105.0°F), and revaccination with Pyramid 5 and Pulmo-guard PHM-1. Within each replicate, all three pens were handled and managed within a 36-hour interval. At an average of approximately 139 to 141 DOF for each pen, all animals were reimplanted with Synovex Choice and vaccinated with an infectious bovine rhinotracheitis virus vaccine (Pyramid IBR, Fort Dodge Animal Health). Within each replicate, all three pens were reimplanted and vaccinated within a 36-hour interval.

Experimental Design

During the processing procedures conducted on arrival at the feedlot, individual animals from each processing group were randomly assigned to one of three experimental groups using a computer-generated randomization table:

- CCFA-3 (n = 3,869)—CCFA (Excede) in the middle one-third of the posterior aspect of the ear at 6.6 mg/kg SC
- CCFA-7 (n = 3,866)—CCFA (Excede) in the middle one-third of the posterior aspect of the ear at 6.6 mg/kg SC
- TILM-3 (n = 3,870)—Tilmicosin (Micotil) in the neck region at 10 mg/kg SC

After allocation, animals in the CCFA-3 and TILM-3 groups were not eligible for subsequent treatment for at least 3 days, whereas animals in the CCFA-7 group were not eligible for subsequent treatment for at least 7 days. Animals in each experimental group were housed in separate pens, with 10 pens in each experimental group for a total of 30 pens. The rectal temperature of each animal was measured at processing. Animals with a rectal temperature of 104.0°F or higher were diagnosed as sick on arrival (SA), treated with florfenicol (Nuflor Injectable Solution; 40 mg/kg SC in the neck region) according to the standard feedlot protocol for initial SA therapy, and randomly allocated to one of the three experimental groups described above using a separate randomization table than that used for non–SA animals. The overall rate of SA in the calves used in the study was 17.86%.

Feeding Program

Standard mixed complete feedlot diets, formulated to meet or exceed the nutritional requirements of feedlot cattle, were offered ad libitum. The feedlot diets were blended by combining dry-rolled corn, high-moisture corn, corn silage, alfalfa hay, corn distiller’s grain solubles, soybean meal, and supplement

### TABLE 1. Baseline Data Summary

<table>
<thead>
<tr>
<th>Baseline Variable</th>
<th>Experimental Group</th>
<th>Standard Error</th>
<th>P Value vs TILM-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCFA-3</td>
<td>CCFA-7</td>
<td>TILM-3</td>
</tr>
<tr>
<td>Initial weight (lb)</td>
<td>562.2</td>
<td>562.7</td>
<td>562.8</td>
</tr>
<tr>
<td>Hip height (inches)</td>
<td>45.72</td>
<td>45.75</td>
<td>45.71</td>
</tr>
</tbody>
</table>

*aCalculated as the summation of the individual animal initial weights, corrected for the shrink from purchase to arrival at the feedlot.

*bAverage hip height of the animals in each pen.
in a modern, batch-milling facility equipped with overhead bins. The supplement was manufactured in a granular form by a commercial feed mill (Farr Better Feeds, Animal Nutrition Division, Cargill, Duncan, NE). The diets were delivered to the pens once or twice daily using truck-mounted mixers on load cells. Daily feed allowances to each pen were recorded. Water was provided ad libitum. The animals were adapted to a finisher diet over a 30- to 35-day period by increasing the proportions of dry-rolled and high-moisture corn and decreasing the proportions of corn silage and alfalfa hay at approximately 7-day intervals.

Sampling
The finishing diets were sampled at approximately 1-month intervals. The samples were analyzed for crude protein, fiber, calcium, phosphorus, and potassium (Servi-Tech Labs, Hastings, NE).

Animal Health
Experienced animal health personnel observed the study animals once or twice daily. The animal health personnel were blind as to the experimental status of each pen. Animals deemed to be “sick” by the animal health personnel were sorted into the catch pen located in each feedlot pen, moved through the mobile hospital facility, and diagnosed and treated according to the written treatment protocols provided by the consulting veterinarians. The same treatment protocols were used for all three experimental groups and included antimicrobials licensed for use in feedlot cattle, such as Nuflor Injectable Solution, enrofloxacin (Baytril 100, Bayer Animal Health), and Liquamycin LA-200.

In this study, the case definition for UF was an elevated rectal temperature (≥104.5°F), a lack of abnormal clinical signs referable to body systems other than the respiratory system, eligibility for UF treatment based on the predefined postallocation intervals for each experimental group, and no previous treatment history for SA or no fever (NF). The case definition for NF was a rectal temperature less than 104.5°F, a lack of abnormal clinical signs referable to body systems other than the respiratory system, eligibility for NF treatment based on the predefined postallocation intervals for each experimental group, and no previous treatment history for SA or UF. Animals identified as “sick” by the pencheckers but not eligible for UF or NF treatment based on the predefined postallocation intervals for each experimental group were returned directly to the home pen from the mobile hospital without treatment.

After receiving initial UF or NF therapy and being returned to their original feedlot pens, animals subsequently selected as “sick” by the pencheckers were diagnosed as UF or NF relapses, provided there was an absence of abnormal clinical signs referable to organ systems other than the respiratory tract. All animals relapsing subsequent to initial UF therapy were defined as UF relapses (i.e., first UF relapse, second UF relapse, or third UF relapse), and all animals relapsing subsequent to initial NF therapy were defined as NF relapses (i.e., first NF relapse, second NF relapse, or third NF relapse). The maximum number of UF or NF treatment regimens permitted for all animals on the study was four (i.e., initial UF or NF therapy, first UF or NF relapse, second UF or NF relapse, and third UF or NF relapse); once an animal was treated as a third UF or NF relapse, no further therapy for UF or NF occurred.

Animals identified as “sick” subsequent to third UF or NF relapse therapy were deemed
### TABLE 2. Morbidity Data Summary

<table>
<thead>
<tr>
<th>Variable</th>
<th>Experimental Group</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCFA-3</td>
<td>CCFA-7</td>
</tr>
<tr>
<td>No. of animals</td>
<td>3,869</td>
<td>3,866</td>
</tr>
<tr>
<td>Initial UF treatment</td>
<td>1,039 (26.85)</td>
<td>1,081 (27.96)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
<tr>
<td>First UF relapse</td>
<td>628 (60.44)</td>
<td>594 (54.95)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
<tr>
<td>Initial NF treatment</td>
<td>579 (14.97)</td>
<td>527 (13.63)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
<tr>
<td>First NF relapse</td>
<td>279 (48.19)</td>
<td>265 (50.28)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
<tr>
<td>Overall Chronicity</td>
<td>230 (5.94)</td>
<td>223 (5.77)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
<tr>
<td>Overall wastage</td>
<td>126 (3.26)</td>
<td>133 (3.44)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
</tbody>
</table>

Numbers in parentheses are percentages.

Relative risk is the ratio of the rate of disease in the CCFA-3 or CCFA-7 group divided by the rate of the disease in the TILM-3 group.

Calculated for each relative risk, corrected for pen and replicate effects using generalized linear modeling techniques. The partially maximized likelihood function was used to calculate CIs. When convergence of the CI could not be attained using the maximized likelihood function, asymptotic normality was used to calculate the CI.

### TABLE 3. Mortality Data Summary

<table>
<thead>
<tr>
<th>Variable</th>
<th>Experimental Group</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCFA-3</td>
<td>CCFA-7</td>
</tr>
<tr>
<td>No. of Animals</td>
<td>3,869</td>
<td>3,866</td>
</tr>
<tr>
<td>Overall mortality</td>
<td>446 (11.53)</td>
<td>460 (11.90)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
<tr>
<td>BRD mortality</td>
<td>310 (8.01)</td>
<td>316 (8.17)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
<tr>
<td>Histophilosis mortality</td>
<td>26 (0.67)</td>
<td>30 (0.78)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
<tr>
<td>Metabolic mortality</td>
<td>36 (0.93)</td>
<td>38 (0.98)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
<tr>
<td>Arthritis mortality</td>
<td>4 (0.10)</td>
<td>2 (0.05)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
<tr>
<td>Miscellaneous mortality</td>
<td>70 (1.81)</td>
<td>74 (1.91)</td>
</tr>
<tr>
<td></td>
<td>CCFA-3 vs TILM-3</td>
<td>CCFA-7 vs TILM-3</td>
</tr>
</tbody>
</table>

Numbers in parentheses are percentages.

Relative risk is the ratio of the rate of disease in the CCFA-3 or CCFA-7 group divided by the rate of the disease in the TILM-3 group.

Calculated for each relative risk, corrected for pen and replicate effects using generalized linear modeling techniques. The partially maximized likelihood function was used to calculate CIs. When convergence of the CI could not be attained using the maximized likelihood function, asymptotic normality was used to calculate the CI.
to be “chronics,” as were animals that were unsuitable to be returned to their designated feedlot pens based on subjective appraisal of the attitude and appearance of each animal. Chronics that did not die during the study were defined as wastage. Finally, all other diseases were treated according to a standard feedlot protocol provided by the consulting veterinarians. All animal health events, including treatment date, presumptive diagnosis, and drug(s) and dose(s) used, were recorded on the chute-side computer system.

Trained feedlot personnel prosected all animals that died during the study using a standardized method and captured the appropriate digital images as outlined in the necropsy protocol written by the study investigators. These images were electronically transferred to the study investigators, and the cause of death for each animal was determined by a veterinarian based on the findings of the gross postmortem examination.

**Marketing**

The cattle were sold under normal marketing procedures: The feedlot manager determined that a replicate, or a portion thereof, was ready for sale based on visual appraisal and/or weight data. The animals were scheduled for slaughter and trucked to the packing plant. When animals were sold, approximately the same numbers of animals were shipped from each experimental group within a replicate to the same packing plant (Tyson Fresh Meats [formerly IBP], Lexington, NE) on the same day.

**Data Collection and Management**

Initial weight and hip height (in inches) were measured for each animal at processing. These data were subsequently imported into a spreadsheet program (Microsoft Excel 2000), and the average initial weight and average hip
height were calculated for each pen. These baseline variables were used to assess the homogeneity of the animals in each experimental group.

The computerized animal health data were verified and summarized. From these data, risk rates for initial UF treatment, first UF relapse, initial NF treatment, first NF relapse, overall chronicity, overall wastage, overall mortality (mortality from all causes), BRD mortality (mortality due to BRD), histophilosis mortality (mortality due to *H. somni* infection), metabolic mortality (mortality due to metabolic disease), arthritis mortality (mortality due to arthritis), and miscellaneous mortality (mortality due to causes other than BRD, histophilosis, metabolic disease, or arthritis) were calculated for each pen (see pages 260 to 261).

The ancillary production variables—slaughter weight, weight gain, carcass weight, dressing percentage, DOF, and daily dry matter intake (DDMI)—were calculated for each pen according to the equations on pages 260 to 261.

The feedlot performance variables—ADG and the dry matter intake:gain ratio (DM:G)—were calculated for each pen. It should be noted that the feedlot performance variables were calculated by two methods: The live weight basis method used the live weights obtained at the time of sale, and the carcass weight basis method used the hot carcass weights obtained from the packing plant. The feedlot performance variables were calculated according to the equations on pages 260 to 261.

The carcass quality grade (QG) and carcass yield grade of each carcass were collected at slaughter. With respect to QG, the proportions

![Figure 1. Cumulative distribution of new UF cases by days on feed.](image-url)
of animals grading USDA Prime, USDA Choice, USDA Select, No Roll, and USDA Standard were calculated for each pen. With respect to yield grade, the proportions of animals grading USDA 1, USDA 2, USDA 3, USDA 4, and USDA 5 were calculated for each pen. Finally, the proportion of heavy carcasses (>980 lb) was calculated for each pen.

**Statistical Analysis**

The data were analyzed using an analytical software program (SAS System for Windows, Release 9.1, SAS Institute, Cary, NC).

The animal health variables were compared between the experimental groups (CCFA-3 versus TILM-3 and CCFA-7 versus TILM-3) using linear logistic regression modeling techniques, controlling for intrapen clustering of disease using the methods described by McDermott, Schukken, and Shoukri.25,26

The baseline, ancillary production, feedlot performance, and carcass grading variables were compared between the experimental groups using least squares analysis of variance for replicate and experimental group effects.27 The baseline variables were tested as covariates of the ancillary production and feedlot performance variables and included in the final model used for comparison of each variable between the experimental groups when significant ($P < .05$) effects were detected.28

**Economic Analysis**

The relative cost effectiveness of the experimental groups was calculated using a computer spreadsheet program (Microsoft Excel 2000) that simulates all economic aspects of feedlot production. The CCFA-3 group was compared
with the TILM-3 group and the CCFA-7 group with the TILM-3 group. In the economic model, the initial weight, final weight, feeder price, slaughter price, processing cost, ration cost, yardage rate, and interest rate were fixed for both experimental groups. The costs of metaphylactic antimicrobial therapy used in the analyses were $12.92/animal for the CCFA-3 and CCFA-7 groups and $9.45/animal for the TILM-3 group. Outcome variables describing animal health, feedlot performance (carcass weight basis ADG and carcass weight basis DM:G), and carcass characteristics of each experimental group were incorporated into the model when significant \( P < .05 \) differences existed between the experimental groups. When there were no significant \( P \geq .05 \) differences between the experimental groups, animal health, feedlot performance, and carcass characteristics of the TILM-3 group were used for both experimental groups in a comparison. All other factors were fixed in the economic simulations. The therapeutic costs used in the economic analysis for UF and NF therapy were $14.99 for Nuflor, $2.49 for Liquamycin LA-200, and $11.06 for Baytril 100. The purchase price used in the analysis was $115.00/100 lb bodyweight (BW), and the discount for QG No Roll carcasses was $8.00/100 lb carcass weight. The interest rate used in the analysis was 4.0%/annum. The value of a dead animal was $0.00. Feed consumed by animals before death was not estimated.

RESULTS

The pen-based summary statistics for the baseline variables are presented in Table 1. All three experimental groups were considered ho-
hogeneous \((P \geq .05)\) with respect to average initial weight and average hip height.

The morbidity and mortality data summaries are presented in Tables 2 and 3. The overall chronicity rate was significantly \((P < .05)\) lower in the CCFA-3 and CCFA-7 groups compared with the TILM-3 group. In addition, the first UF relapse rate was significantly \((P < .05)\) lower in the CCFA-7 group and numerically \((P = .380)\) lower in the CCFA-3 group than in the TILM-3 group. There were no significant \((P \geq .05)\) differences in initial UF treatment, initial NF treatment, first NF relapse, or overall wastage rates between the experimental groups. The cumulative distributions of new UF and NF cases are presented in Figures 1 and 2. With respect to mortality, overall mortality, BRD mortality, and metabolic mortality were significantly \((P < .05)\) lower in the CCFA-3 and CCFA-7 groups compared with the TILM-3 group. There were no significant \((P \geq .05)\) differences in histophilosis mortality, arthritis mortality, or miscellaneous mortality rates between the experimental groups. The cumulative distributions of overall mortality, BRD mortality, and metabolic mortality are presented in Figures 3 through 5.

The ancillary production data summary is presented in Table 4. The DDMI of the CCFA-3 \((P = .019)\) and CCFA-7 \((P = .036)\) groups was significantly higher than the DDMI of the TILM-3 group. In addition, the DOF of the CCFA-3 group \((P = .039)\) was significantly \((P < .05)\) higher and the DOF of the CCFA-7 group was numerically \((P = .050)\) higher than the TILM-3 group. However, there were no significant \((P .05)\) differences in slaughter weight, weight gain, carcass weight,
and dressing percentage between the experimental groups.

The feedlot performance variables are summarized in Table 5. On both a live weight basis and a carcass weight basis, ADG was significantly ($P < .05$) higher in the CCFA-3 group and numerically ($P = .10$) higher in the CCFA-7 group than in the TILM-3 group. There were no significant ($P \geq .05$) differences in DM:G between the experimental groups on either a live weight basis or a carcass weight basis.

The carcass characteristic data summary is presented in Table 6. The proportion of carcasses grading QG No Roll was significantly ($P < .05$) lower in the CCFA-3 and CCFA-7 groups as compared with the TILM-3 group. There were no significant ($P \geq .05$) differences between the experimental groups in the other carcass characteristic variables evaluated in the study.

In the economic analysis, there was an advantage of $22.05/animal in the CCFA-3 group compared with the TILM-3 group as the result of a lower overall mortality rate, an improved ADG, and a lower rate of QG No Roll carcasses, even though the metaphylactic antimicrobial cost was higher for the CCFA-3 group than for the TILM-3 group. In addition, there was an advantage of $18.98/animal in the CCFA-7 group compared with the TILM-3 group as a result of a lower overall mortality rate, a lower first UF relapse rate, and a lower rate of QG No Roll carcasses, even though, again, the metaphylactic antimicrobial cost was higher for the CCFA-7 group than for the TILM-3 group.

The results of this study demonstrate that it is more cost effective to administer metaphylactic CCFA on feedlot arrival to calves at

Figure 5. Cumulative distribution of metabolic mortality by days on feed.
ultrahigh risk of developing UF/BRD than to administer metaphylactic tilmicosin, regardless of whether animals receiving CCFA are eligible for subsequent UF/BRD detection, diagnosis, and treatment 3 or 7 days later.

**DISCUSSION**

The results of this study demonstrate that the metaphylactic use of CCFA in recently weaned, auction market–derived feedlot calves at ultrahigh risk of developing UF/BRD is more cost effective than the metaphylactic use of tilmicosin because of reduced morbidity and mortality rates, higher ADG, and improved carcass quality grade in calves receiving CCFA, even though the metaphylactic antimicrobial cost is higher for CCFA than for tilmicosin. Moreover, the results of this study demonstrate that the differences observed between metaphylactic CCFA and metaphylactic tilmicosin are more likely related to differences in the metaphylactic efficacy of the two antimicrobials than differences in UF/BRD detection, diagnosis, and treatment strategies because similar improvements were observed in both the CCFA-3 and CCFA-7 groups. Furthermore, given that the magnitude of almost all of the differences observed between the two CCFA groups and the TILM-3 group favored the CCFA-3 group (as opposed to the CCFA-7 group), it is unlikely that purposely delaying UF/BRD detection, diagnosis, and treatment more than 3 days after administering metaphylaxis is associated with positive outcome effects.

In the economic analysis, the economic advantage of $22.05/animal in the CCFA-3 group compared with the TILM-3 group was the result of a $1.14/animal improvement in ADG, a $23.41/animal improvement in death loss, a $1.02/animal improvement in QG No Roll, and a $3.52/animal higher metaphylactic antimicrobial cost at processing. In the sensitivity analysis, every $10.00/100 lb BW change in the purchase price was positively correlated

<table>
<thead>
<tr>
<th>TABLE 4. Ancillary Production Data Summary</th>
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<tbody>
<tr>
<td>Ancillary Production Variablea</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Slaughter weightb (lb)</td>
</tr>
<tr>
<td>Weight gainc (lb)</td>
</tr>
<tr>
<td>Carcass weightd (lb)</td>
</tr>
<tr>
<td>Dressing percentagee</td>
</tr>
<tr>
<td>Days on feedf</td>
</tr>
<tr>
<td>Daily dry-matter intakeg (lb/animal/day)</td>
</tr>
</tbody>
</table>

aSee pages 260 to 261 for the equations used to determine ancillary production variables.
bRepresents the average net live weight of animals sold for slaughter.
cRepresents the average weight gain of animals sold for slaughter.
dRepresents the average carcass weight of animals sold for slaughter.
eRepresents the average dressing percentage of animals sold for slaughter.
fRepresents the average number of days on feed of animals sold for slaughter.
gRepresents the pounds of feed consumed per animal per day.
with a $2.04/animal change in the economic advantage of CCFA-3 over TILM-3. Similarly, the economic advantage of $18.98/animal in the CCFA-7 group compared with the TILM-3 group was the result of a $0.29/animal improvement in the first UF relapse rate, a $20.98/animal improvement in death loss, a $1.23/animal improvement in QG No Roll, and a $3.52/animal higher cost of metaphylactic antimicrobial administration at processing.

In the sensitivity analysis, every $10.00/100 lb BW change in the purchase price was positively correlated with a $1.82/animal change in the economic advantage of CCFA-7 over TILM-3.

In the experimental design, one of the strategies used to control for the inherent day-to-day variation observed in carcass grading at packing plants was to ensure that the same numbers of animals from each experimental group were marketed to the same packing plant on the same day. However, because the mortality rates observed in the TILM-3 group were higher than those observed in the CCFA-3 and CCFA-7 groups, this resulted in the marketing of a small but consistently higher proportion of animals in each TILM-3 pen in the first marketing groups from each replicate, which is evident by the fact that the DOF of the TILM-3 group averaged 2 days less than that of the CCFA-3 and CCFA-7 groups. It is unlikely that this small difference materially influenced either the feedlot performance or carcass characteristic outcome variables. If the experimental design of future large-pen commercial feedlot studies includes strategies to market the same proportion of animals in each experimental group in a replicate on the same day, instead of the same number of animals, this “study design–induced” observation can be avoided while still managing to control for the inherent day-to-day variation observed in carcass grading at packing plants.

In terms of feedlot performance, it should be noted that the observed improvements in ADG in the CCFA-3 and CCFA-7 groups were associated with increased DDMI as opposed to improvements in DM:G. As a result, the economic impact of the observed improvements in ADG affects only fixed-day costs, such as interest and yardage. This is an important observation because in studies in which ADG is the only feedlot performance variable

<table>
<thead>
<tr>
<th>Performance Variable</th>
<th>Experimental Group</th>
<th>Standard Error</th>
<th>P Value vs TILM-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCFA-3</td>
<td>CCFA-7</td>
<td>TILM-3</td>
</tr>
<tr>
<td>Average daily gain</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Live weight basis</td>
<td>2.78</td>
<td>2.76</td>
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<td>Carcass weight basis</td>
<td>2.89</td>
<td>2.86</td>
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<td>Dry matter intake:gain ratio</td>
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<tr>
<td>Live weight basis</td>
<td>6.45</td>
<td>6.49</td>
<td>6.46</td>
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<tr>
<td>Carcass weight basis</td>
<td>6.21</td>
<td>6.25</td>
<td>6.23</td>
</tr>
</tbody>
</table>

*See pages 260 to 261 for the equations used to determine performance variables.

*Expressed as lb/animal/day. The effect of animals that died has been removed from the average daily gain values.

*The effect of animals that died has been removed from the dry matter intake:gain ratio values.

*Calculated using shrunk live weights obtained before slaughter.

*Calculated using carcass weights obtained at slaughter, converted to live weights using a fixed dressing percentage.
measured (i.e., feed conversion data are not available), it would be erroneous to assume that improvements in ADG are always associated with improvements in feed conversion.

**CONCLUSION**

The results of this study demonstrate that the metaphylactic use of CCFA is more cost effective than the metaphylactic use of tilmicosin in recently weaned, auction market–derived steer and bull calves that are at ultrahigh risk of developing UF/BRD and entering feedlots in Nebraska during autumn. The metaphylactic use of CCFA, although higher in cost, reduced morbidity and mortality rates, increased ADG, and improved carcass quality grade compared with tilmicosin. Although these results can be applied to other calves at ultrahigh risk of developing UF/BRD, it may not be appropriate to directly extrapolate the results of this study to other populations of feedlot cattle that are at lower risk for developing UF/BRD.

**ACKNOWLEDGMENTS**

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**REFERENCES**

