# Article

## A comparison of 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever/bovine respiratory disease

Brian K. Wildman, Tye Perrett, Sameeh M. Abutarbush, P. Timothy Guichon, Tom J. Pittman, Calvin W. Booker, Oliver C. Schunicht, R. Kent Fenton, G. Kee Jim

**Abstract —** The aim of this study was to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever (UF)/bovine respiratory disease (BRD). At feedlot arrival, 3882 calves were enrolled in the study and randomly allocated to 2 groups, which were housed by group in 12 pens. At the time of allocation, 1 group (MLV3-BT2) received a multivalent, modified-live viral vaccine containing infectious bovine rhinotracheitis virus (IBRV) and types I and II bovine viral diarrhea virus (BVDV), as well as a *Mannheimia haemolytica* (MH) and *Pasteurella multocida* bacterin-toxoid. The other group (MLV4-BT1) received a vaccine containing IBRV, type I BVDV, bovine respiratory syncytial virus, and parainfluenza-3 virus, as well as a MH bacterin-toxoid. At an average of 69 days post arrival, the groups received their respective viral vaccines. The initial UF treatment, overall chronicity, overall wastage, overall mortality, and BRD mortality rates were significantly ($P < 0.05$) lower in the MLV3-BT2 group than in the MLV4-BT1 group. Average daily gain and the proportions of yield grade Canada 3 and quality grade E carcasses were significantly ($P < 0.05$) higher in the MLV3-BT2 group than in the MLV4-BT1 group. No significant ($P \geq 0.05$) difference in the dry matter intake to gain ratio was detected between the 2 groups. In economic terms, there was a net advantage of $20.86 CDN/animal in the MLV3-BT2 group. This study demonstrates that it is more cost effective to use an MLV3-BT2 vaccination program than a MLV4-BT1 vaccination program in feedlot calves at ultra-high risk of developing UF/BRD.

**Résumé — Comparaison de 2 programmes de vaccination chez des veaux en parcs d'engraissement présentant un très haut risque de développer une fièvre indifférenciée/maladie respiratoire bovine.** Le but de cette étude était de comparer 2 programmes de vaccination chez des veaux en parcs d'engraissement présentant un très haut risque de développer une fièvre indifférenciée (FI)/maladie respiratoire bovine (MRB). À l'arrivée en parcs d'engraissement, 3882 veaux ont été inclus dans l'étude et attribués au hasard à 2 groupes répartis par groupes dans 12 parcs. Au moment de la répartition, 1 groupe (MLV3-BT2) a reçu un vaccin polyvalent composé de virus vivants modifiés contenant le virus de la rhinotrachéite infectieuse bovine (VRIB) et les types 1 et 2 du virus de la diarrhée virale bovine (VDVB) ainsi qu'un bactérine-anatoxine de *Mannheimia haemolytica* (MH) et de *Pasteurella multcida*. L'autre groupe (MLV4-BT1) a reçu un vaccin contenant le VRIB, le VDVB de type 1, le virus respiratoire syncytial bovin et le virus de la parainfluenza-3 ainsi qu'une bactérine-anatoxine de MH. Les groupes ont reçu leurs vaccins respectifs en moyenne 69 jours après leur arrivée. Le traitement initial de la FI, la chronicité globale, la déperdition globale, la mortalité globale et les taux de mortalité reliés à la MRB étaient significativement plus bas ($P < 0,05$) dans le groupe MLV3-BT2 que dans le groupe MLV4-BT1. Le gain quotidien moyen et les proportions de carcasses de grades Canada 3 et qualité E étaient significativement plus élevés ($P < 0,05$) dans le groupe MLV3-BT2 que dans le groupe MLV4-BT1. Aucune différence significative ($P \geq 0,05$) dans la prise de matière sèche par rapport au facteur de gain n'a été détectée entre les 2 groupes. En termes économiques, il y avait un net avantage de 20,86 dollars canadiens par animal pour le groupe MLV3-BT2. Cette étude démontre qu'il est plus rentable d'utiliser le programme de vaccination MLV3-BT2 que le programme MLV4-BT1 chez les veaux en parcs d'engraissement à très haut risque de développer une FI/MRB.

(Traduit par Docteur André Blouin)

Can Vet J 2008;49:463–472

Feedlot Health Management Services Ltd., PO Box 140, Okotoks, Alberta T1S 2A2 (Wildman, Perrett, Guichon, Pittman, Booker, Schunicht, Fenton, Jim); Department of Clinical Sciences, Faculty of Veterinary Medicine, Jordan University of Science and Technology, P.O Box 3030, Irbid, Jordan, 22110 (Abutarbush).

Address all correspondence and reprint requests to Dr. Calvin W. Booker; e-mail: calvinb@feedlothealth.com

This project was funded by research grants from Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri, USA and Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario.

## Introduction

Undifferentiated fever (UF), also known as bovine respiratory disease (BRD) complex or shipping fever, continues to be one of the most economically significant health problems in calves entering beef feedlots (1–9). The management of this disease is complex and involves vaccination of feedlot cattle upon arrival at the feedlot with modified-live viral vaccines (MLVs) and bacterin-toxoids (BTs) containing antigens isolated from animals with UF/BRD. The choice of MLVs and BTs used is based on the predicted risk of developing UF/BRD in any given population of feedlot animals. The predicted UF/BRD risk for a particular group of feedlot calves is based on such factors as age class (calf versus yearling), body weight (often a proxy for age), procurement method (sale barn versus ranch direct), amount of commingling before and after arrival, and previous vaccination and management history. Recently, several studies in feedlot calves at high or ultra-high risk of developing UF/BRD have compared the efficacy and cost-effectiveness of multivalent versus univalent or bivalent viral vaccines (6,9). Multivalent viral vaccines immunize animals against infectious bovine rhinotracheitis virus (IBRV), parainfluenza-3 virus ($PI_3V$), bovine viral diarrhea virus (BVDV), and bovine respiratory syncytial virus (BRSV). Univalent viral vaccines immunize animals against IBRV only, while bivalent viral vaccines immunize animals against both IBRV and $PI_3V$ (6,9). In these studies, multivalent vaccine programs were superior to univalent or bivalent vaccine programs because of reductions in UF/BRD morbidity, overall chronicity, and/or overall wastage rates, as well as improvements in average daily gain (ADG).

Express 3 [Boehringer Ingelheim (Canada) Burlington, Ontario], hereafter referred to as MLV3, is a new multivalent, modified-live viral vaccine containing IBRV and types I and II BVDV. In studies conducted by the manufacturer, animals that were vaccinated with MLV3 had higher antibody titers to BVDV than animals vaccinated with other commercially available, multivalent modified live viral vaccines (10,11). However, the impact of this finding on animal health, feedlot performance, and carcass characteristic variables in commercial feedlot production has not been thoroughly studied.

Viruses have not been the only pathogens associated with UF/BRD. Several bacterial pathogens have been associated with the UF/BRD complex. *Mannheimia haemolytica* (MH) has been described as the most likely cause of fibrinous pneumonia, either as a primary pathogen or secondary to other viral or bacterial pathogens (12). *Pasteurella multocida* (PM) has been isolated from UF/BRD cases; however, the exact role of this pathogen in the development of the UF/BRD complex is not well understood (12). Experimental challenge models and commercial field studies have demonstrated that using MH/PM bacterin-toxoids in feedlot animals results in lower UF/BRD occurrence and/or lower overall mortality rates (13–15).

Pulmo-guard PHM-1 [Boehringer Ingelheim (Canada)], hereafter referred to as BT2, includes MH and PM bacterin-toxoids. Similar to the case in MLV3, there are limited large-scale, commercial feedlot studies to compare the efficacy of this bacterin-toxoid to other commercial MH/PM bacterin-toxoids. In addition, the impact of this bacterin-toxoid on animal health, feedlot performance, and carcass characteristic variables in commercial feedlot production has not been thoroughly studied.

The aim of this study was to compare a vaccine program comprised of MLV3 and BT2 to a vaccination program comprised of a modified-live viral vaccine containing IBRV, type I BVDV, BRSV, and $PI_3V$, hereafter referred to as MLV4, and a bacterin-toxoid containing MH, hereafter referred to as BT1 (Bovi-Shield 4 and One Shot; respectively, Pfizer Animal Health, Pfizer Canada, Kirkland, Quebec) in feedlot calves at ultra-high risk of developing UF/BRD.

## Materials and methods

### Study overview

At feedlot arrival, 3882 calves were enrolled in a commercial field study. Study animals were randomly allocated to 1 of 2 vaccination programs, each of which included vaccines at the time of allocation and at an average of 69 d post arrival. Study animals were housed in pens, segregated by experimental group, and followed from the time of allocation to slaughter. Outcome variables describing animal health, feedlot performance, and carcass characteristics were measured and compared between the 2 groups. An economic model was used to determine the financial impact of significant ($P < 0.05$) differences in outcome variables between the 2 groups.

### Study facilities

The study was conducted at a commercial feedlot in western Canada located near Strathmore, Alberta. The feedlot design is representative of standard designs used in western Canada and the feedlot has a capacity of approximately 24 000 animals. The animals were housed in open-air, dirt-floor pens that are arranged side by side with the central feed alleys and 20% porosity wood-fence windbreaks. Each pen has a capacity of approximately 330 animals. There are 2 hospital facilities and 1 processing facility located at the feedlot. Each facility is equipped with a hydraulic chute, an individual animal scale, a chute-side computer for animal health data collection, and separating alleys to facilitate the return of animals to designated pens. Open-air hospital pens are located adjacent to each hospital. Also, there are several receiving pens at the feedlot that are located near the processing facility.

### Study animals

The animals enrolled in the study were crossbred beef steer and bull calves purchased from auction markets throughout western Canada. Animals were transported by truck to the feedlot after their assembly at auction markets. The animals allocated to the study were approximately 8 to 10 mo old. The average weights of individual animals in the pens that were enrolled in the study were between 635 lb (288.6 kg) and 653 lb (296.8 kg). Study animals arrived at the feedlot from October 23 to December 14, 2002.

Upon arrival at the feedlot, the animals were moved through a hydraulic chute for a group of procedures known collectively as processing. All animals received an ear tag and a zeranol implant (Ralgro; Schering-Plough Animal Health, Division of Schering

Canada, Pointe Claire, Quebec). In addition, a multivalent clostridial/*Histophilus somni* (HS) bacterin-toxoid [Fermicon 7-Somnugen; Boehringer Ingelheim (Canada)] and topical ivermectin (Ivomec Pour-On; Merial Canada, Baie D'Urfé, Quebec), at a dose of 1 mL/10 kg body weight (BW), were administered to each animal. Animals in the first 4 replicates received parenteral metaphylactic long-acting oxytetracycline (Tetradure LA 300; Merial Canada), 30 mg/kg BW, IM, and animals in replicates 5 and 6 received parenteral metaphylactic tilmicosin (Micotil; Provel, Division, Eli Lilly Canada, Guelph, Ontario), 10 mg/kg BW, SC. In addition, all bulls were castrated at processing.

## Experiment design

During processing, individual animals from each processing group were randomly assigned, using a computer generated randomization table, to 1 of 2 experimental groups as follows: the MLV3-BT2 group, which received MLV3 and BT2 at allocation and MLV3 at an average days on feed (DOF) of approximately 69 d; or the MLV4-BT1 group**,** which received MLV4 and BT1 at allocation and MLV4 at an average DOF of approximately 69 d. Animals from each experimental group were assembled in designated pens by experimental group until each pen contained up to 334 animals. Replicates (1 pen from each experimental group) were filled consecutively until there were 6 replicates with a total of 12 pens. In total, 1942 animals were allocated to the MLV3-BT2 group and 1940 animals were allocated to the MLV4-BT1 group.

At an average DOF for each processing group of approximately 6 to 7 d, all animals in both experimental groups were moved through the processing facility for individual rectal temperature measurement and mass antimicrobial treatment with either long-acting oxytetracycline (Oxymycin LA; Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario), 20 mg/kg BW, IM, or florfenicol (Nuflor; Schering-Plough Animal Health, Division of Schering Canada), 40 mg/kg BW, SC, dependent on individual animal rectal temperature.

At an average DOF of 69 d for each pen, all animals were implanted with either a zeranol implant (Ralgro) or an estradiol/trenbolone acetate combination implant (Synovex Plus; Wyeth Animal Health, Division of Wyeth Canada), dependent on individual animal BW, and vaccinated with the same multivalent viral vaccine that each animal had received at processing (MLV3 or MLV4). At an average DOF of 139 d for each pen, all animals that received a zeranol implant on day 69 were implanted with either a zeranol implant or an estradiol/trenbolone acetate implant, dependent on individual animal BW. Animals that received an estradiol/trenbolone acetate implant at an average DOF of 69 d did not receive an implant at an average DOF of 139 d.

## Feeding program

Standard complete feedlot diets, formulated to meet the nutritional requirements of feedlot cattle (Nutritional Requirements for Beef Cattle, National Research Council, 1996), and water were offered ad libitum. The diets were delivered to the pens once or twice daily. Daily feed allowances to each pen were recorded.

The diets used in the study were blended by combining dry-rolled barley, dry-rolled corn, barley silage, tallow, medicated premix, and granular supplement in truck-mounted mixer boxes (Harshmixer; Hydraulics Unlimited Manufacturing, Eaton, Colorado, USA) equipped with electronic load cells. The medicated premix contained chlortetracycline and sulphamethazine (Aureo S-700 G; Alpharma Canada Corporation, Mississauga, Ontario) and was formulated into the complete feedlot diet to provide 350 mg/animal/d of each antimicrobial. The diet containing medicated premix was fed until an average DOF for each pen of approximately 56 d was reached. A commercial feed mill (Landmark Feeds, Strathmore, Alberta) manufactured the granular supplement and the medicated premix. The animals were adapted to a finisher diet over a 32- to 38-day period by increasing the proportions of dry-rolled barley and corn and decreasing the proportion of barley silage at approximately 5-day intervals.

Silage was sampled weekly and the dry matter content was determined. From these data, the weekly average dry matter content of each diet was calculated and used to calculate the weekly dry matter intake for each pen.

## Sampling

An ear notch (ear skin biopsy) was obtained from all animals that died during the study. In replicates where the overall mortality during the 1st part of the feeding period was higher than expected, an ear skin biopsy was collected from all animals in both experimental groups at an average DOF of 69 d. Ear skin biopsies were submitted for immunohistochemical staining for BVDV (Prairie Diagnostic Services, Saskatoon, Saskatchewan).

## Animal health

Study animals were observed once or twice daily by experienced animal health personnel. The animal health personnel were blinded as to the experimental status of each pen. Animals identified as "sick" by animal health personnel were moved to the hospital facility, diagnosed, and treated according to standard protocols provided by the consulting veterinarians. A diagnosis of UF was made when an animal showed evidence of depression, as characterized by lack of response to stimulation, reluctance to move, and/or abnormal posture/carriage of the head; a lack of abnormal clinical signs referable to body systems other than the respiratory system; a rectal temperature $> 40.5$°C; and no previous treatment history for UF/BRD. A diagnosis of BRD with no fever (NF) was made when an animal showed evidence of depression, as characterized by lack of response to stimulation, reluctance to move, and/or abnormal posture/carriage of the head; a lack of abnormal clinical signs referable to body systems other than the respiratory system; a rectal temperature $\leq 40.5$°C, and no previous treatment history for UF/BRD.

All animal health events, including treatment date, presumptive diagnosis, drug(s) used, and dose(s) administered were recorded on the chute-side computer system [Feedlot Health Animal Record Management (FHARM) Feedlot Health

**Table 1.** Definitions of ancillary production variables used in a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever/bovine respiratory disease

| Ancillary production variable | Definition |
|---|---|
| Slaughter weight | (total slaughter weight) ÷ (the number of animals slaughtered) |
| Weight gain | (average slaughter weight) - (average initial weight) |
| Carcass weight | (total carcass weight) ÷ (the number of carcasses) |
| Dressing percentage | (total carcass weight) ÷ (total slaughter weight) × 100% |
| Dressing percentage adjusted | dressing percentage adjusted for the significant ($P < 0.05$) effect of the proportion of steers in each pen |
| Days on feed (DOF) | (average slaughter date) - (average allocation date) |
| Daily dry matter intake (DDMI) | [total dry matter fed (100% dry matter basis)] ÷ (the number of animal days) |
| Daily dry matter intake adjusted | DDMI adjusted for the significant ($P < 0.05$) effect of the average initial weight in each pen |

**Table 2.** Definitions of feedlot performance variables used in a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever/bovine respiratory disease

| Feedlot performance variable | Definition |
|---|---|
| Average daily gain (ADG) live weight basis | (total net slaughter weight + total weight of animals shipped for salvage slaughter + total weight of animals that died) - (total initial weight) ÷ (the number of animal days) |
| ADG carcass weight basis | (total carcass weight) ÷ (a fixed dressing percentage for each packing plant) + (total weight of animals shipped for salvage slaughter + total weight of animals that died - total initial weight) ÷ (the number of animal days) |
| Dry matter intake to gain ratio (DM:G) live weight basis | (DDMI) ÷ (ADG live weight basis) |
| DM:G carcass weight basis | (DDMI) ÷ (ADG carcass weight basis) |

DDMI — daily dry matter intake

**Table 3.** Definitions of animal health variables used in a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever (UF)/bovine respiratory disease (BRD)

| Animal health variable | Definition |
|---|---|
| Initial UF treatment rate | (number of animals initially treated for UF) ÷ (the number of animals allocated) × 100% |
| First UF relapse rate | (number of first UF relapses) ÷ (the number of animals initially treated for UF) × 100% |
| Initial NF treatment rate[a] | (number of animals initially treated for NF) ÷ (the number of animals allocated) × 100% |
| First NF relapse rate[a] | (number of first NF relapses) ÷ (the number of animals initially treated for NF) × 100% |
| Overall chronicity rate | (number of animals designated as chronic) ÷ (the number of animals allocated) ×100% |
| Overall wastage rate | (number of animals designated as chronic that did not die) ÷ (the number of animals allocated) × 100% |
| Overall mortality rate | (number of mortalities due to all causes) ÷ (the number of animals allocated) × 100% |
| BRD mortality rate | (number of mortalities due to BRD) ÷ (the number of animals allocated) |
| Histophilosis mortality rate[b] | (number of mortalities due to histophilosis) ÷ (the number of animals allocated) × 100% |
| Metabolic mortality rate | (number of mortalities due to metabolic disease) ÷ (the number of animals allocated) × 100% |
| Arthritis mortality rate | (number of mortalities due to arthritis) ÷ (the number of animals allocated) × 100% |
| Miscellaneous mortality rate | (number of mortalities due to causes other than BRD, histophilosis, metabolic disease, or arthritis) ÷ (the number of animals allocated) × 100% |

[a] NF — no fever
[b] Histophilosis — disease due to *Histophilus somni* infection

Management Services Ltd., Okotoks, Alberta]. Animals that died during the study were weighed, after which a postmortem examination was performed by a veterinarian from Feedlot Health Management Services Ltd. The cause of death, which was established based on gross postmortem findings, and diagnosis were recorded in FHARM.

## Marketing

Cattle were marketed under normal marketing procedures, whereby the feedlot manager, based on visual appraisal and/or weight data, determined when animals were ready for sale. When animals were sold, approximately the same numbers of animals were shipped from each experimental group within a replicate to the same packing plant on the same day.

## Data collection and management

At allocation, data for the baseline variables — initial weight, hip height (inches), and sex (steer or bull) — were recorded for each animal. This was done to assess the homogeneity of the animals in each experimental group at the start of the study. The recorded data were subsequently entered into a spreadsheet program (Microsoft Excel 97; Microsoft Corporation, Redmond, Washington, USA) and verified. The ancillary production variables — slaughter weight, weight gain, carcass weight, dressing percentage, DOF, and daily dry matter intake (DDMI) — were calculated for each pen as indicated in Table 1.

The feedlot performance variables, average daily gain (ADG) and the dry matter intake to gain ratio (DM:G), were calculated for each pen, as indicated in Table 2. The feedlot performance variables were calculated using 2 methods: the live weight basis method, which used the live weights obtained at the time of sale, and the carcass weight basis method, which used the hot carcass weights obtained from the packing plants.

Grading data on all carcasses were obtained at slaughter. Regarding quality grade (QG), the proportions of carcasses grading Canada Prime, Canada AAA, Canada AA, Canada A,

**Table 4.** Economic model input values and sensitivity analysis from a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever (UF)/bovine respiratory disease

| Description | Unit | Input value | Change evaluated in sensitivity analysis | Economic impact[a] |
|---|---|---|---|---|
| Initial UF treatment cost | $/animal | $25.00 | $1.00 | $0.05 |
| Purchase price | $/100 lb body weight | $110.00 | $10.00 | $1.69 |
| Yardage rate | $/day | $0.17 | $0.01 | $0.09 |
| Interest rate | %/year | 4.50% | 1.00% | $0.31 |
| Wastage cost | $/wastage animal | $360.25 | $100.00 | $1.04 |
| Yield grade Canada 3 discount | $/100 lb carcass weight | -$3.00 | $1.00 | $0.28 |
| Quality grade E discount | $/100 lb carcass weight | -$80.00 | $10.00 | $0.18 |

[a] All economic impact values are expressed in $CDN/animal. The values should be interpreted as the effect on the economic analysis that is associated with the input value changes evaluated in the sensitivity analysis

**Table 5.** Summary of baseline data collected in a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever/bovine respiratory disease

| | Experimental group | | | |
|---|---|---|---|---|
| Baseline variable | MLV3-BT2[a] | MLV4-BT1[b] | $S_{\bar{x}}$[c] | *P*-value |
| Initial weight [lb (kg)][c] | 642.7 (291.5)[f] | 644.5 (292.3)[f] | 0.7 (0.3) | 0.140 |
| Steers (%)[d] | 75.96 | 76.12 | 0.91 | 0.902 |
| Hip height [in (cm)][e] | 46.06 (116.99) | 46.10 (117.09) | 0.02 (0.05) | 0.104 |

[a] Animals in the MLV3-BT2 group received a modified-live viral vaccine containing infectious bovine rhinotracheitis virus (IBRV), type I and II bovine viral diarrhea virus (BVDV), and a *Mannheimia haemolytica* (MH) and *Pasteurella multocida* (PM) bacterin-toxoid [Express 3 and Pulmo-guard PHM-1; respectively, Boehringer Ingelheim (Canada) Burlington, Ontario]. There were 6 pens and 1942 animals in the MLV3-BT2 group

[b] Animals in the MLV4-BT1 group received a modified-live viral vaccine containing IBRV, type I BVDV, bovine respiratory syncytial virus, and parainfluenza-3 virus and a MH bacterin-toxoid (Bovi-Shield 4 and One Shot; respectively, Pfizer Animal Health, Pfizer Canada, Kirkland, Quebec). There were 6 pens and 1940 animals in the MLV4-BT1 group

[c] The standard error of the mean calculated from the analysis of variance

[d] Initial weight for each pen was calculated as the summation of the individual animal initial weights, corrected for the shrink from purchase to arrival at the feedlot

[e] Steers is the average proportion of steers in each pen

[f] Numbers presented for each group are least squares means from the analysis of variance

B1 (devoid of marbling and/or $<$ 4 mm grade fat), B2 (yellow fat), B4 (dark red rib eye), and E (pronounced masculinity) were calculated for each pen. Regarding yield grade (YG), the proportions of Canada Prime, Canada AAA, Canada AA, and Canada A carcasses within each pen that graded Canada 1, Canada 2, or Canada 3 were calculated for each pen.

Computerized animal health data retrieved from FHARM were summarized by using a database management program (Microsoft Access 97; Microsoft Corporation). Using these data, risk rates for initial UF treatment, 1st UF relapse, initial NF treatment, 1st NF relapse, overall chronicity (animals designated as chronic due to all causes), overall wastage (animals designated as chronic that did not die), overall mortality (mortality due to all causes), BRD mortality (mortality due to BRD), histophilosis mortality (mortality due to *Histophilus 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 (Table 3).

## Statistical analyses

Data were analyzed by using an analytical software program (SAS System for Windows, Release 8.00; SAS Institute, Cary, North Carolina, USA). The baseline, ancillary production, feedlot performance, and carcass characteristic variables were compared between the experimental groups by using least squares analysis of variance for replicate and experimental group effects, using the pen as the unit of analysis (16). The baseline variables were tested as covariates of the performance variables, using an analysis of covariance. Those covariates with significant ($P < 0.05$) effects were included in the final model used for the comparison of each variable between the experimental groups (17). The animal health variables were compared between the experimental groups, using Poisson regression in a log linear model for replicate and experimental group effects and generalized estimating equations to control for intra-pen clustering of disease, as previously described (18,19).

## Economic analysis

The relative cost-effectiveness of the experimental groups was calculated by using a proprietary computer spreadsheet program (Microsoft Excel 97). In the economic model, the initial [655 lb (297.1 kg)] and final [1350 lb (612.3 kg)] weights, feeder and slaughter prices, treatment regime and ration costs, and yardage and interest rates were fixed for both experimental groups. The vaccination program costs used in the economic model were $4.98 CDN/animal for the MLV3-BT2 group and $2.53 CDN/animal for the MLV4-BT1 group. An economic value was not ascribed to animals designated as "chronics." The value of a dead animal was $0.00. Feed consumed prior to death was not estimated. The input values used in the economic model are summarized in Table 4.

**Table 6.** Summary of morbidity data collected in a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever (UF)/bovine respiratory disease

| | Experimental group | | | | |
|---|---|---|---|---|---|
| Morbidity variable | MLV3-BT2[a] | MLV4-BT1[b] | Relative risk[c] | 95% CI[d] | *P*-value |
| Initial UF treatment | 327 (16.84)[f] | 416 (21.44)[f] | 0.78 | 0.69–0.89 | < 0.001 |
| First UF relapse | 136 (41.59) | 182 (43.75) | 0.94 | 0.80–1.11 | 0.498 |
| Initial NF treatment[e] | 169 (8.70) | 186 (9.59) | 0.91 | 0.74–1.11 | 0.340 |
| First NF relapse[e] | 66 (39.05) | 85 (45.70) | 0.86 | 0.67–1.09 | 0.206 |
| Overall chronicity | 69 (3.55) | 113 (5.82) | 0.61 | 0.45–0.81 | < 0.001 |
| Overall wastage | 32 (1.65) | 52 (2.68) | 0.61 | 0.39–0.95 | 0.027 |

[a] Animals in the MLV3-BT2 group received a modified-live viral vaccine containing infectious bovine rhinotracheitis virus (IBRV), type I and II bovine viral diarrhea virus (BVDV), and a *Mannheimia haemolytica* (MH) and *Pasteurella multocida* (PM) bacterin-toxoid [Express 3 and Pulmo-guard PHM-1; respectively, Boehringer Ingelheim (Canada) Burlington, Ontario]. There were 6 pens and 1942 animals in the MLV3-BT2 group

[b] Animals in the MLV4-BT1 group received a modified-live viral vaccine containing IBRV, type I BVDV, bovine respiratory syncytial virus, and parainfluenza-3 virus and a MH bacterin-toxoid (Bovi-Shield 4 and One Shot; respectively, Pfizer Animal Health, Pfizer Canada, Kirkland, Quebec). There were 6 pens and 1940 animals in the MLV4-BT1 group

[c] Relative Risk is the ratio of the rate of disease in the MLV3-BT2 group divided by the rate of the disease in the MLV4-BT1 group

[d] 95% CI is the 95% confidence interval calculated for each relative risk, corrected for pen and replicate effects using Poisson regression in a log linear model and generalized estimating equations

[e] NF — no fever

[f] Numbers presented are numbers of animals with percentages in parentheses

**Table 7.** Summary of mortality data collected in a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever/bovine respiratory disease (BRD)

| | Experimental group | | | | |
|---|---|---|---|---|---|
| Mortality variable | MLV3-BT2[a] | MLV4-BT1[b] | Relative risk[c] | 95% CI[d] | *P*-value |
| Overall mortality | 101 (5.20)[e] | 148 (7.63)[e] | 0.68 | 0.53–0.87 | 0.002 |
| BRD mortality | 44 (2.27) | 79 (4.07) | 0.56 | 0.38–0.79 | 0.001 |
| Histophilosis mortality | 28 (1.44) | 31 (1.60) | 0.90 | 0.54–1.50 | 0.693 |
| Metabolic mortality | 9 (0.46) | 9 (0.46) | 1.00 | 0.39–2.55 | 1.000 |
| Arthritis mortality | 3 (0.15) | 5 (0.26) | 0.60 | 0.22–1.63 | 0.248 |
| Miscellaneous mortality | 17 (0.88) | 24 (1.24) | 0.71 | 0.45–1.12 | 0.188 |

[a] Animals in the MLV3-BT2 group received a modified-live viral vaccine containing infectious bovine rhinotracheitis virus (IBRV), type I and II bovine viral diarrhea virus (BVDV), and a *Mannheimia haemolytica* (MH) and *Pasteurella multocida* (PM) bacterin-toxoid [Express 3 and Pulmo-guard PHM-1; respectively, Boehringer Ingelheim (Canada) Burlington, Ontario]. There were 6 pens and 1942 animals in the MLV3-BT2 group

[b] Animals in the MLV4-BT1 group received a modified-live viral vaccine containing IBRV, type I BVDV, bovine respiratory syncytial virus, and parainfluenza-3 virus and a MH bacterin-toxoid (Bovi-Shield 4 and One Shot; respectively, Pfizer Animal Health, Pfizer Canada, Kirkland, Quebec). There were 6 pens and 1940 animals in the MLV4-BT1 group

[c] Relative Risk is the ratio of the rate of disease in the MLV3-BT2 group divided by the rate of the disease in the MLV4-BT1 group

[d] 95% CI is the 95% confidence interval calculated for each relative risk, corrected for pen and replicate effects using Poisson regression in a log linear model and generalized estimating equations

[e] Numbers presented are numbers of animals with percentages in parentheses

The actual values of outcome variables describing feedlot performance (ADG carcass weight basis and DM:G carcass weight basis), carcass characteristics, and animal health of each experimental group were incorporated into the model if significant ($P < 0.05$) differences existed between the experimental groups. When no statistically significant ($P \geq 0.05$) difference existed between the experimental groups for an outcome variable, the MLV4-BT1 group value of that variable was used for both experimental groups.

## Results

Pen-based summary statistics for the baseline variables are presented in Table 5. The groups were considered homogeneous ($P \geq 0.05$) with respect to average initial weight, average hip height, and average proportion of steers within each pen.

The pen-based data for morbidity and mortality variables are summarized in Tables 6 and 7, respectively. The initial UF treatment, overall chronicity, overall wastage, overall mortality, and BRD mortality rates were significantly ($P < 0.05$) lower in the MLV3-BT2 group than in the MLV4-BT1 group. There were no significant ($P \geq 0.05$) differences in the other morbidity and mortality rates between the experimental groups.

Slaughter and carcass weight, weight gain, DOF, DDMI, and adjusted DDMI were significantly ($P < 0.05$) higher in the MLV3-BT2 group than in the MLV4-BT1 group (Table 8). There was no significant ($P \geq 0.05$) difference in dressing percentage between experimental groups.

Based on live and carcass weight data, ADG was significantly ($P < 0.05$) higher in the MLV3-BT2 group than in the MLV4-BT1 group (Table 9). However, there was no significant ($P \geq 0.05$) difference in DM:G between the experimental groups.

Carcass grading data revealed that the proportion of YG Canada 3 and QG E carcasses were significantly ($P < 0.05$) higher in the MLV3-BT2 group than in the MLV4-BT1 group (Table 10). However, there were no significant ($P \geq 0.05$) differences in the proportions of other YG and QG variables between the 2 experimental groups.

**Table 8.** Summary of ancillary production data collected in a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever/bovine respiratory disease

| | Experimental group | | | |
|---|---|---|---|---|
| Ancillary production variable | MLV3-BT2[a] | MLV4-BT1[b] | $S_{\bar{x}}$[c] | *P*-value |
| Slaughter weight (kg) | 594.8[d] | 587.6[d] | 1.2 | 0.009 |
| Weight gain (kg) | 303.2 | 295.2 | 1.4 | 0.009 |
| Carcass weight (kg) | 365.6 | 360.9 | 0.8 | 0.008 |
| Dressing percentage (%) | 61.46 | 61.41 | 0.06 | 0.579 |
| Dressing percentage adjusted (%) | 61.47 | 61.41 | 0.03 | 0.231 |
| Days on feed (d) | 224.5 | 223.9 | 0.1 | 0.024 |
| Daily dry matter intake (kg/animal/d) | 8.47 | 8.28 | 0.03 | 0.008 |
| Daily dry matter intake adjusted (kg/animal/d) | 8.49 | 8.25 | 0.01 | 0.002 |

[a] Animals in the MLV3-BT2 group received a modified-live viral vaccine containing infectious bovine rhinotracheitis virus (IBRV), type I and II bovine viral diarrhea virus (BVDV) and a *Mannheimia haemolytica* (MH) and *Pasteurella multocida* (PM) bacterin-toxoid [Express 3 and Pulmo-guard PHM-1; respectively, Boehringer Ingelheim (Canada) Burlington, Ontario]. There were 6 pens and 1942 animals in the MLV3-BT2 group

[b] Animals in the MLV4-BT1 group received a modified-live viral vaccine containing IBRV, type I BVDV, bovine respiratory syncytial virus, and parainfluenza-3 virus and a MH bacterin-toxoid (Bovi-Shield 4 and One Shot; respectively, Pfizer Animal Health, Pfizer Canada, Kirkland, Quebec). There were 6 pens and 1940 animals in the MLV4-BT1 group

[c] The standard error of the mean calculated from analysis of variance

[d] Numbers presented for each group are least squared means from the analysis of variance

**Table 9.** Summary of performance data collected in a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever/bovine respiratory disease

| | Experimental group | | | |
|---|---|---|---|---|
| Performance variable | MLV3-BT2[a] | MLV4-BT1[b] | $S_{\bar{x}}$[c] | *P*-value |
| Average daily gain (kg/animal/d) | | | | |
| Live weight basis | 1.33[d] | 1.28[d] | 0.01 | 0.008 |
| Carcass weight basis | 1.40 | 1.35 | 0.01 | 0.004 |
| Dry matter intake to gain ratio | | | | |
| Live weight basis | 6.38 | 6.49 | 0.05 | 0.176 |
| Carcass weight basis | 6.05 | 6.16 | 0.05 | 0.168 |

[a] Animals in the MLV3-BT2 group received a modified-live viral vaccine containing infectious bovine rhinotracheitis virus (IBRV), type I and II bovine viral diarrhea virus (BVDV), and a *Mannheimia haemolytica* (MH) and *Pasteurella multocida* (PM) bacterin-toxoid [Express 3 and Pulmo-guard PHM-1; respectively, Boehringer Ingelheim (Canada) Burlington, Ontario]. There were 6 pens and 1942 animals in the MLV3-BT2 group

[b] Animals in the MLV4-BT1 group received a modified-live viral vaccine containing IBRV, type I BVDV, bovine respiratory syncytial virus, and parainfluenza-3 virus and a MH bacterin-toxoid (Bovi-Shield 4 and One Shot; respectively, Pfizer Animal Health, Pfizer Canada, Kirkland, Quebec). There were 6 pens and 1940 animals in the MLV4-BT1 group

[c] The standard error of the mean calculated from the analysis of variance

[d] Numbers presented for each group are least squares means from the analysis of variance

In the economic analysis, there was a net advantage of $20.86 CDN/animal in the MLV3-BT2 group when compared with the MLV4-BT1 group. A detailed summary of the economic analysis is presented in Table 11 and a summary of the economic sensitivity analysis is presented in Table 4.

Three animals in the MLV3-BT2 group and 8 animals in the MLV4-BT1 group were diagnosed, using IHC testing of postmortem ear skin biopsies, as persistently infected (PI) with BVDV. Tissues from 1 additional dead animal in the MLV3-BT2 group (replicate 2) demonstrated a weak positive IHC staining pattern for BVDV, which means that the animal was either transiently infected with BVDV or PI with a strain of BVDV causing an atypical IHC skin staining pattern. In replicate 2, where an ear notch was collected from all surviving animals at an average DOF of 69 d and tested for BVDV, using IHC, 1 animal was identified as PI with BVDV. This PI animal was in the MLV3-BT2 group and survived to slaughter. As a result, the prevalence of PI animals in this study was at least 0.31% (12/3882).

## Discussion

There are several differences between the 2 vaccination programs compared in this study, but it is unknown which difference(s) was (were) responsible for the changes in the outcome variables observed in the MLV3-BT2 group. In contrast to the MLV4-BT1 group, cattle in the MLV3-BT2 group were immunized to PM and type II BVDV, but not to BRSV and $PI_3V$. Perhaps, the presence of PM and type II BVDV is more important than that of BRSV and $PI_3V$ in vaccination programs for feedlot cattle at ultra-high risk of developing UF/BRD. There was also a difference in the BVDV strains that were used in the 2 vaccination programs. The BVDV strains in MLV3 were Singer (type I) and NVSL 296c (type II). On the other hand, MLV4 contained only type I BVDV (NADL strain). Differences between the IBRV antigens were also present between the 2 vaccination programs: MLV3 contained the Colorado 1 strain while MLV4 contained the Resbo strain. Leukotoxin and lipopolysaccharide induced immunity are important factors in protection against MH infection. The 2 vaccines used in this trial may have contained different proportions

**Table 10.** Summary of carcass characteristic data collected in a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever/bovine respiratory disease

| Carcass characteristic variable | Experimental Group | | $S_{\bar{x}}$[n] | *P*-value |
|---|---|---|---|---|
| | MLV3-BT2[l] | MLV4-BT1[m] | | |
| Yield grade | | | | |
| Canada 1[a] | 66.47[o] | 69.49[o] | 1.38 | 0.181 |
| Canada 2[b] | 20.99 | 21.46 | 1.09 | 0.773 |
| Canada 3[c] | 12.54 | 9.05 | 0.56 | 0.007 |
| Quality grade | | | | |
| Canada Prime[d] | 1.09 | 1.13 | 0.21 | 0.914 |
| Canada AAA[e] | 41.67 | 38.56 | 1.98 | 0.317 |
| Canada AA[f] | 52.00 | 55.48 | 2.20 | 0.315 |
| Canada A[g] | 4.64 | 3.99 | 0.69 | 0.536 |
| B1[h] | 0.06 | 0.05 | 0.06 | 0.971 |
| B2[i] | 0.00 | 0.06 | 0.04 | 0.363 |
| B4[j] | 0.33 | 0.74 | 0.16 | 0.142 |
| E[k] | 0.22 | 0.00 | 0.05 | 0.025 |

[a] Yield grade (YG) Canada 1 is the proportion of quality grade (QG) Prime, AAA, AA, and A carcasses within a pen that graded YG Canada 1
[b] Yield Grade Canada 2 is the proportion of QG Prime, AAA, AA, and A carcasses within a pen that graded YG Canada 2
[c] Yield grade Canada 3 is the proportion of QG Prime, AAA, AA, and A carcasses within a pen that graded YG Canada 3
[d] Quality grade Canada Prime is the proportion of carcasses within a pen that graded QG Canada Prime
[e] Quality grade Canada AAA is the proportion of carcasses within a pen that graded QG Canada AAA
[f] Quality grade Canada AA is the proportion of carcasses within a pen that graded QG Canada AA
[g] Quality grade Canada A is the proportion of carcasses within a pen that graded QG Canada A
[h] Quality grade B1 is the proportion of carcasses within a pen that graded QG B1 (devoid of marbling and/or $<$ 4 mm grade fat)
[i] Quality grade B2 is the proportion of carcasses within a pen that graded QG B2 (yellow fat)
[j] Quality grade B4 is the proportion of carcasses within a pen that graded QG B4 (dark red rib eye)
[k] Quality grade E is the proportion of carcasses within a pen that graded QG E (pronounced masculinity)
[l] Animals in the MLV3-BT2 group received a modified-live viral vaccine containing infectious bovine rhinotracheitis virus (IBRV), type I and II bovine viral diarrhea virus (BVDV), and a *Mannheimia haemolytica* (MH) and *Pasteurella multocida* (PM) bacterin-toxoid [Express 3 and Pulmo-guard PHM-1; respectively, Boehringer Ingelheim (Canada) Burlington, Ontario]. There were 6 pens and 1942 animals in the MLV3-BT2 group
[m] Animals in the MLV4-BT1 group received a modified-live viral vaccine containing IBRV, type I BVDV, bovine respiratory syncytial virus, and parainfluenza-3 virus and a MH bacterin-toxoid (Bovi-Shield 4 and One Shot; respectively, Pfizer Animal Health, Pfizer Canada, Kirkland, Quebec). There were 6 pens and 1940 animals in the MLV4-BT1 group
[n] The standard error of the mean calculated from the analysis of variance
[o] All numbers are expressed as percentages and are least squares means from the analysis of variance

**Table 11.** Economic analysis summary from a study to compare 2 vaccination programs in feedlot calves at ultra-high risk of developing undifferentiated fever (UF)/bovine respiratory disease

| Variable | Economic advantage in the MLV3-BT2 group[a] compared with the MLV4-BT1 group[b] |
|---|---|
| Initial UF treatment | $4.49[c] |
| Overall wastage | $3.76 |
| Overall mortality | $17.76 |
| Average daily gain | $2.66 |
| Yield grade Canada 3 | -$0.85 |
| Quality grade Canada E | -$1.43 |
| Vaccine program cost | -$2.49 |
| Total economic advantage for the MLV3-BT2 group | $23.90 |

[a] Animals in the MLV3-BT2 group received a modified-live viral vaccine containing infectious bovine rhinotracheitis virus (IBRV), type I and II bovine viral diarrhea virus (BVDV), and a *Mannheimia haemolytica* (MH) and *Pasteurella multocida* (PM) bacterin-toxoid [Express 3 and Pulmo-guard PHM-1; respectively, Boehringer Ingelheim (Canada) Burlington, Ontario]. There were 6 pens and 1942 animals in the MLV3-BT2 group
[b] Animals in the MLV4-BT1 group received a modified-live viral vaccine containing IBRV, type 1 BVDV, bovine respiratory syncytial virus, and parainfluenza-3 virus and a MH bacterin-toxoid (Bovi-Shield 4 and One Shot; respectively, Pfizer Animal Health, Pfizer Canada, Kirkland, Quebec). There were 6 pens and 1940 animals in the MLV4-BT1 group
[c] All values are expressed in $CDN/animal

of the MH antigens, leukotoxin and lipopolysaccharide. Specific proprietary information related to the adjuvants in each vaccine may also have affected the measured outcomes, because the specific adjuvant properties of vaccines likely play a significant role in the way an antigen is presented to the host's immune system and, subsequently, the host's immunological response. This immunological response may also be affected by the actual amount of virus antigen titer that is in each viral vaccine.

In many vaccine studies, vaccine groups are commingled and housed in the same pens, because the commingled experimental design is easier to conduct and ensures equal levels of disease exposure for all vaccine groups. However, if one vaccine protocol is more effective than another, the level of disease within a pen could be significantly reduced for all animals in that pen, not just the animals receiving the more effective vaccine. The reverse may also occur, as a less effective vaccine protocol

could allow for an increased level of disease within a pen for all anmals, not just the animals receiving the less effective vaccine. The net result of this so-called "herd effect" tends to bias the results of commingled vaccine studies toward the null hypothesis; that is, artificially minimizing the true difference between vaccine groups. In the current study, animals in each experimental group were housed separately from each other to remove the potential bias created by the herd effect, and statistical techniques were used to account for the clustering of animal health events (a proxy for disease exposure) within specific pens. Note that under general feedlot conditions, the exposure to pathogens such as MH, HS, IBRV, and BVDV are considered significant for all cattle (4,8,9,12). The relative exposure to other pathogens, such as BRSV, PI3V, and PM, has not been fully evaluated.

In this study, the prevalence of PI animals was at least 0.31% (12/3882), but the true prevalence of PI animals was likely higher than what was estimated, because the number of PI animals that survived to slaughter in 5 of the replicates was unknown. There was a potential difference in the number of PI animals present between the 2 groups, because in animals that died, there were only 3 PI animals from 3 pens in the MLV3-BT2 group versus 8 PI animals from 5 pens in the MLV4-BT1 group. However, as noted previously, this difference cannot be interpreted at face value, because the number of PI animals that survived to slaughter in each group was unknown. The effect of PI animals on the health and performance of pen-mates is highly variable. Few studies have been done to investigate this effect, but the results are not consistent (20–22). In 1 study, the incidence of respiratory disease morbidity was significantly higher in pens containing PI animals or in pens adjacent to pens containing PI animals (20) than in pens that did not contain PI animals. In addition, cattle housed in pens adjacent to pens that contained PI animals were found to have increased initial and relapse treatment rates for respiratory disease and increased overall mortality (20). However, in 2 other studies, it appeared that the overall health of animals is protected by the presence of a PI animal in a pen, when compared with the health of animals in pens without a P1 animal (21,22).

The economic analysis used in this study was conservative; whereby, biologic differences between 2 vaccination programs for each animal's health, feedlot performance, or carcass characteristic variable were only incorporated into the model if the probability of chance alone in producing the difference was below a specified level ($P < 0.05$). This method was selected because it is conservative, straightforward, and directly ascribes an economic effect to a significant ($P < 0.05$) difference in a biologic outcome variable. When this method is used, pre-study sample size calculations are necessary to ensure that each study is designed with sufficient power to detect economically important differences in biologic outcome variables. This method does not consider the economic impact of differences between experimental groups where the probability of chance alone in producing the observed differences is greater than the specified level and creates the possibility of underestimating the relative economic impact of each group. However, this risk is theoretical and is outweighed by the risks of overstating economic impacts by imputing the effects of all observed differences into an economic model.

In summary, this study demonstrates that using an MLV3-BT2 vaccination program is more cost-effective than using a MLV4-BT1 vaccination program in fall-placed feedlot calves at ultra-high risk of developing UF/BRD. The economic model attributed an advantage to the MLV3-BT2 group due to a lower rate of initial treatment for UF, less wastage, and a reduction in overall mortality. In addition, cattle in the MLV3-BT2 had a higher rate of gain but were discounted for being over fat (YG 3) and having more animals with pronounced masculinity (QG E).

## Authors' contributions

Drs. Booker and Abutarbush wrote and edited the manuscript. Dr. Booker analyzed the data. Drs. Wildman, Perrett, Schunicht, Fenton, Guichon, Jim, and Pittman helped in designing and conducting the experiment and collecting the samples.

## Acknowledgments

We thank the staff of Strangmuir Holdings Ltd., Strathmore, Alberta, for their assistance and cooperation in conducting this study. CVJ

## References

1. Guichon PT, Booker CW, Jim GK. Comparison of two formulations of oxytetracycline given prophylactically to reduce the incidence of bovine respiratory disease in feedlot calves. Can Vet J 1993;34:736–741.
2. Jim GK, Booker CW, Guichon PT. Comparison of a combination of oxfendazole and fenthion versus ivermectin in feedlot calves. Can Vet J 1992;33:599–604.
3. Harland RJ, Jim GK, Guichon PT, Townsend HGG, Janzen ED. Efficacy of parenteral antibiotics for disease prophylaxis in feedlot calves (abstract). Can Vet J 1991;32:163–168.
4. Jim GK, Guichon PT, Shaw G. Protecting feedlot calves from pneumonic pasteurellosis. Vet Med 1988;83:1084–1087.
5. Merrill JK, Jim GK, Guichon PT, Booker CW. A comparison of the prophylactic use of tilmicosin injection and long-acting oxytetracycline injection on morbidity, mortality, and performance of feedlot calves. J Anim Sci 1994;72(Suppl. 1):143(Abstract 547).
6. Schunicht OC, Booker CW, Jim GK, Guichon PT, Wildman BK, Hill BW. Comparison of a multivalent viral vaccine program versus a univalent viral vaccine program on animal health, feedlot performance, and carcass characteristics of feedlot calves. Can Vet J 2003;44:43–50.
7. Schunicht OC, Guichon PT, Booker CW, et al. A comparison of prophylactic efficacy of tilmicosin and a new formulation of oxytetracycline in feedlot calves. Can Vet J 2002;43:355–362.
8. Booker CW, Guichon PT, Jim GK, Schunicht OC, Harland RJ, Morley PS. Seroepidemiology of undifferentiated fever in feedlot calves in western Canada. Can Vet J 1999;40:179–184.
9. Animal Health Group, Pfizer Canada Inc. Comparison of Resvac 2/Somubac versus Resvac 4/Somubac in feedlot calves. Technical Bulletin Resvac/Somubac vaccine 2002.
10. Boehringer Ingelheim (Canada) Ltd. A Comparative Evaluation of Titer Responses in Weaned Beef Heifers Following Vaccination with Express Versus Two Competitive products. Technical Report 2001–05, 2001.
11. Boehringer Ingelheim (Canada) Ltd. Evaluation of the Anamnestic Response in Replacement Heifers Vaccinated with Two Different MLV Vaccines. Technical Report 2001–10, 2001.
12. Radostits OM, Gay CC, Blood DC, Hinchcliff KW. Veterinary Medicine. 9th ed: A Textbook of Diseases of Cattle, Sheep, Pigs, Goats and Horses. 2000:831–851.
13. Shewen PE, Wilkie BN. Vaccination of calves with leukotoxic culture supernatant from *Pasteurella haemolytica*. Can J Vet Res 1988;52:30–36.
14. Jim GK, Guichon PT, Shaw G. Protecting calves from pneumonic pasteurellosis. Vet Med 1988;83:1084–1087.

15. Rice Conlon JA, Gallo GF, Shewen PE, Adlam C. Comparison of protection of experimentally challenged cattle vaccinated once or twice with a *Pasteurella haemolytica* bacterial extract vaccine. Can J Vet Res 1995;59:179–182.
16. Snedecor GW, Cochran WG. Statistical Methods. 7th ed. Ames, Iowa: Iowa State Univ Pr, 1987:175–191.
17. SAS Institute Inc. SAS/STAT User's Guide, Version 6, 4th ed. Cary, North Carolina: SAS Institute Inc. 1989;1,2:1686.
18. McDermott JJ, Schukken YH. A review of methods used to adjust for cluster effects in explanatory epidemiological studies of animal populations. Prev Vet Med 1994;18:155–173.
19. McDermott JJ, Schukken YH, Shoukri MM. Study design and analytic methods for data collected from clusters of animals. Prev Vet Med 1994;18:175–191.
20. Loneragan GH, Thomson DU, Montgomery DL, Mason GL, Larson RL. Prevalence, outcome and health consequences associated with persistent infection with bovine viral diarrhea in feedlot cattle. J Am Vet Med Assoc 2005;226:595–601.
21. O'Connor AM, Sorden SD, Apley MD. Association between the existence of calves persistently infected with bovine viral diarrhea virus and commingling on pen morbidity in feedlot cattle. Am J Vet Res 2005;66:2130–2134.
22. Booker CW, Abutarbush SM, Morley PS, et al. The effect of bovine viral diarrhea virus infections on health and performance of feedlot cattle. Can Vet J 2008;49:253–260.

# Book Review
## Compte rendu de livre

### Equine Injury, Therapy and Rehabilitation, 3rd ed.

Bromily MW. Blackwell Publishing, Ames, Iowa, 2007. ISBN 978-1-4051-5061-3.

The 3rd edition of Mary Bromily's popular book on equine rehabilitation is a soft cover book comprising 218 pages divided into 8 chapters and 6 appendices.

As a human trained physiotherapist, the author is very clear regarding the interpretation of the *Veterinary Surgeon's Act,* United Kingdom, and the implications therein for nonveterinarians administering treatment to horses. The *Act* is included as Appendix 1 and the 1st page of the book includes a disclaimer to remind readers of the *Act*. Readers from other parts of the world would have to familiarize themselves with the regulations of their own country and jurisdiction of their licensing body.

The book is written using some Oxford English terminology, which is confusing to Canadian readers. For example, the term "shells" refers to what we in Canada would call "caps" (retained deciduous teeth) and the term "pin-toed" refers to our term "pigeon-toed."

The book provides a cursory overview of topics pertaining to equine rehabilitation, including anatomy and physiology of the musculoskeletal system, the process of injury and repair, assessing the patient, several treatment modalities, comparison of the equine back to the human back, and common rider injuries.

Some of the modalities covered include more widely known therapies such as: the application of hot and cold, massage, magnetic therapy, therapeutic ultrasound, light and laser therapy, transcutaneous electrical nerve stimulation (TENS), hydrotherapy, and range of motion. Other more recent modalities are also covered, such as thalasso therapy. The author has also included a short section on long reining horses and ridden work, which may be of particular interest to a nonriding equine practitioner.

Written in layman's terms, coverage of the individual modalities is too brief for this book to provide a reference for a veterinarian wanting to learn and to apply the specific techniques. For the most part each modality is defined and the premise behind which they are purported to have beneficial effects is discussed. However, an equine practitioner may find the book helpful as an overview of some of the newer modalities.

*Reviewed by* ***Jenifer Parks, DVM, NCCP Certified Riding Coach,*** *Associate Chair — Animal Health Technology Program — Edmonton Campus, Northern Alberta Institute of Technology, 11762–106 Street NW, Edmonton, Alberta T5G 2R1.*