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A Comparison of two *Mannheimia haemolytica* Immunization Programs in Feedlot Calves at High Risk of Developing Undifferentiated Fever/Bovine Respiratory Disease

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Abstract

A field study was conducted to compare the relative effect of a *Mannheimia haemolytica* toxoid (Presponse® SQ, Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario) and a *Mannheimia haemolytica-Pasteurella multocida* bacterin-toxoid (Pulmo-guard™ PHM-1, Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario). Upon arrival at the feedlot, 5,128 animals were enrolled in the study and randomly assigned to two experimental groups. Animals in the first group received Presponse® SQ (PSQ), while animals in the second group received Pulmo-guard™ PHM-1 (PHM-1). Animals in each experimental group were housed in separate pens with 10 pens per experimental group.

With respect to morbidity, the first undifferentiated fever relapse, overall chronicity and overall wastage rates were significantly ($P<0.05$) lower in the PSQ group as compared to the PHM-1 group. There were no significant ($P\geq0.05$) differences in any of the other morbidity or mortality outcome variables between the experimental groups. In addition, there were no significant ($P\geq0.05$) differences in average daily gain or the dry matter intake-to-gain ratio between groups. The PSQ group had a higher proportion of carcasses grading YG Canada 3 ($P<0.05$) than the PHM-1 group. In the economic analysis, there was an advantage of $4.06 CDN/animal in the PSQ group. Based on these results, it is more cost-effective to use PSQ than PHM-1 in feedlot calves at high risk of developing bovine respiratory disease in western Canada.

Keywords: bovine, feedlot, bovine respiratory disease, vaccination

Résumé

Une étude sur le terrain a été menée pour comparer l'effet relatif d'une toxoïde provenant de Mannheimia haemolytica (Presponse® SQ, Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario) et une autre provenant de Mannheimia haemolytica-Pasteurella multocida (Pulmo-guard™ PHM-1, Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario). À leur arrivée au parc d'engraissement, 5128 individus ont été sélectionnés pour l'étude et alloués au hasard dans deux groupes expérimentaux. Dans le premier groupe, les animaux recevaient la toxoïde Presponse® SQ alors que les animaux du second groupe recevaient la toxoïde Pulmo-guard™ PHM-1. Les animaux de chaque groupe étaient logés dans des enclos différents à raison de 10 enclos par groupe.

En ce qui concerne la morbidité, la première rechute de fièvre non différenciée, la chronicité dans son ensemble et les taux de perte en général étaient significativement moins élevés dans le groupe Presponse SQ que dans le groupe Pulmo-guard PHM-1 ($P<0.05$). Il n'y avait pas de différence significative ($P\geq0.05$) entre les deux groupes au niveau de toutes les autres variables reliées à la morbidité ou à la mortalité. De plus, il n'y avait pas de différence ($P\geq0.05$) entre les deux groupes au niveau du gain moyen quotidien ou du rapport entre la prise alimentaire de matières sèches et le gain. La

proportion de carcasses de grade YG Canada 3 était plus élevée dans le groupe Presponse SQ que dans le groupe Pulmo-guard PHM-1 group (P<0.05). Du point de vue économique, il y avait un gain additionnel de 4.06$ (canadien) par animal dans le groupe Presponse SQ. À la lumière de ces résultats, il est plus économique d'utiliser le produit Presponse SQ que le produit Pulmo-guard PHM-1 chez les veaux en engraissement qui sont à haut risque de développer des maladies respiratoires bovines dans l'ouest canadien.

Introduction

Undifferentiated fever (UF), also called bovine respiratory disease (BRD) complex or shipping fever, is a clinically and economically important disease of calves entering feedlots.[4,5,10,12,14,21,22,32] The etiology and pathogenesis of UF are multifactorial, and unless aggressive plans for prevention and treatment are used in high-risk populations, this disease can result in substantial mortality and loss of production. Multiple bacterial and viral pathogens have been associated with the development of UF, including *Mannheimia haemolytica* (MH), *Pasteurella multocida* (PM), *Mycoplasma* spp, *Histophilus somni*, infectious bovine rhinotracheitis (IBR) virus, bovine viral diarrhea (BVD) virus and bovine respiratory syncytial (BRS) virus.[1,2,8,9,15-18,23-25,31,33] Although a single virus or species of bacteria may be capable of causing respiratory disease in cattle, generally more than one pathogen is associated with the pathogenesis of clinical disease and associated lesions of the lung.[3]

High antibody titers to BRD pathogens are protective and reduce the occurrence of subsequent UF in calves entering feedlots.[7,8,11,13,16-18,29,34] While pre-arrival immunization programs may be effective at increasing antibody titers at the time of feedlot arrival, many animals arriving at commercial feedlots in western Canada are procured through the auction market system, with no known previous immunization history. As a result, a number of "on-arrival" immunization programs have been developed in attempt to increase antibody titers to targeted bacterial and viral pathogens of feedlot cattle as soon as possible after arrival.

One of the potential components of on-arrival immunization programs for cattle at high risk of developing UF are MH (+/- PM) bacterins-toxoids. In a recent study comparing two vaccination programs, the program that included a MH-PM bacterin-toxoid[a] had significant ($P<0.05$) improvements in morbidity and mortality outcome variables as compared to a positive control group.[35] That article reports several differences between the two vaccination programs compared in the study that may have been responsible for the improvements in animal health observed, including differences in MH and PM antigens. As a result, Pulmo-guard™ PHM-1[a] became part of many on-arrival immunization programs in cattle at high risk of developing UF in western Canada.

Presponse® SQ[b] is an adjuvanted MH toxoid licensed in Canada for use in cattle as an aid in the prevention of pneumonic pasteurellosis by stimulating immunity to MH. Presponse SQ should be administered to healthy cattle at least 14 days prior to shipping or exposure to stress which may precipitate infectious conditions. The label states that only a single dose is necessary to confer active immunity. It has been hypothesized that Presponse SQ may be as cost-effective or more cost-effective than Pulmo-guard PHM-1. There are no relevant data from properly conducted, large-scale field studies to support or refute this hypothesis.

The purpose of this study was to determine the relative efficacy and cost-effectiveness of a Presponse SQ immunization program as compared to a Pulmo-guard PHM-1 immunization program in feedlot calves at high risk of developing UF.

Materials and Methods

General Overview

In this field trial, feedlot calves at high risk of developing UF were randomly allocated at feedlot arrival to one of two experimental groups included in the study. Animals in the same experimental group were housed within the same pen, and the pen was the experimental unit. Study animals were followed from allocation until harvest, and outcome variables were measured to compare animal health, feedlot performance and carcass characteristics of animals that received Presponse SQ (PSQ group) to those that received Pulmo-guard PHM-1 (PHM-1 group). Statistical analyses were used to determine the probability of whether or not differences in outcome variables between the experimental 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 ($P<0.05$) were subsequently incorporated into economic models to determine the relative economic impact of each experimental group.

Study Facilities

The study was conducted at two commercial feedlots in Alberta. The feedlots have capacities of approximately 30,000 animals at one site and 50,000 animals at the other site. The basic design of each feedlot is representative of the standard designs used in Alberta. Animals are housed in open-air, dirt-floor pens that are arranged side-by-side with central feed alleys and 20% porosity wood-fence windbreaks. Pens are designed to house approximately 200 to 300 animals/pen. Each feedlot is equipped with two or three hospital facilities. Each hospital facility is equipped with a hydraulic chute,

an individual animal scale, a chute-side computer for the collection of animal health data[c] and separation alleys to facilitate the return of animals to designated pens. Open-air hospital pens are located adjacent to each hospital facility. Also, there are several receiving pens located adjacent to an enclosed processing facility at each feedlot.

Study Animals

Animals utilized in the study were exotic crossbred male calves (steers and bulls) purchased from auction markets throughout western Canada. Animals were transported by truck to the feedlots after assembly at auction markets. Animals were allocated to the study from November 16, 2005 to December 4, 2005. Average weights of calves in the pens allocated to the study were between 635 lb and 670 lb (289 kg – 305 kg).

Within 24 hours of arrival at the feedlot, the calves were moved through a hydraulic chute and processed according to the recommendations of the consulting feedlot veterinarians. All animals were ear tagged to provide unique individual animal identification. In addition, each animal received a modified-live IBR virus, parainfluenza-3 (PI_3) virus, BVD virus (types I and II) and bovine respiratory syncytial (BRS) virus combination vaccine,[d] a multivalent clostridial/*Histophilus somni* bacterin-toxoid,[e] intramuscular long-acting oxytetracycline[f] at a dosage of 13.6 mg/lb (30 mg/kg) body weight (BW), an estradiol benzoate/trenbolone acetate growth implant[g] and topical avermectin[h] at a dosage of 2.2 mL/22.05 lb (1.0 mL/10 kg) BW. All intact bulls with normal presentation of the scrotum and testicles were banded. Intact bulls with abnormal presentation of the scrotum and/or testicles were surgically castrated.

At 65 to 72 days-on-feed (DOF) for each pen, all animals were re-immunized with a modified-live IBR virus, PI_3 virus, BVD virus (type I) and BRS virus combination vaccine.[i] At 134 to 140 DOF for each pen, all animals were re-implanted with an estradiol benzoate/trenbolone acetate growth implant[j] and vaccinated with a modified-live IBR virus and PI_3 virus combination vaccine.[k] Within each replicate, pens from each experimental group were handled and re-vaccinated or re-implanted on the same date.

Experimental Design

During the processing procedures, individual animals from each processing group were weighed and randomly assigned, using a computer-generated randomization table, to one of two experimental groups as follows: PSQ, which received Presponse SQ upon arrival at the feedlot; or PHM-1, which received Pulmo-guard PHM-1 upon arrival at the feedlot.

Animals in each experimental group were assembled in designated pens until those pens contained up to 274 animals, which took two to four days/pen. At each site, replicates (one pen from each experimental group) were filled consecutively until there were five replicates with a total of 10 pens. A total of 2,564 animals were allocated to the PSQ group, and 2,564 animals were allocated to the PHM-1 group.

Sampling

The finishing diets were sampled at approximately one-month intervals. These samples were analyzed at a commercial feed testing laboratory[l] for crude protein, acid detergent fiber, calcium, phosphorus, potassium, magnesium, sodium and salt. An ear skin biopsy was collected from each animal that died during the study. The ear skin biopsies were tested for BVD virus using immunohistochemistry (IHC)[m] to identify animals that were persistently infected (PI) with BVD virus.

Feeding Program

Standard mixed complete feedlot diets, formulated to meet or exceed the nutritional requirements of feedlot cattle,[n] were offered *ad libitum*. The feedlot diets were blended by combining tempered-rolled grain, hay, barley silage, tallow, medicated premix and granular supplement in truck-mounted mixer boxes equipped with electronic load cells. Upon completion of allocation for each replicate, the animals were adapted to a finisher diet over a 35-50 day period by increasing the proportions of tempered-rolled grain and decreasing the proportion of barley silage. Diet changes occurred on the same date for each pen within each replicate.

The medicated premix, which contained chlortetracycline,[o] was added to the mixed, complete, feedlot diets to provide 1,000 mg/animal/day of chlortetracycline. Diets containing the medicated premix were fed to each pen until approximately 56 days DOF. The standard granular supplement contained monensin[p] and chlortetracycline, formulated into the mixed complete feedlot diets at levels of 11.4 mg/lb (25 mg/kg) diet dry matter (DM) and 15.9 mg/lb (35 mg/kg) DM, respectively. The standard granular supplement was included in the mixed complete diets from arrival to a minimum of five days prior to shipment of harvest animals. The withdrawal granular supplement contained monensin and tylosin,[q] formulated into the mixed complete feedlot diets at levels of 11.4 mg/lb (25 mg/kg) DM and 5 mg/lb (11 mg/kg) DM, respectively. The withdrawal granular supplement was included in the mixed complete diets for a minimum of five days prior to shipment of harvest animals. The granular supplements and medicated premix were manufactured by a commercial feed mill.[r] The diets were delivered to the pens daily in a standardized manner for all study pens using truck-mounted mixers on load cells. Daily feed allowances to each pen were recorded. Water was provided *ad libitum*.

Animal Health

The study animals were observed daily by experienced animal health personnel. The animal health personnel were masked as to the experimental status of each pen. Animals deemed to be "sick" by the animal health personnel were moved to the hospital facility, diagnosed and treated as per the written treatment protocols provided by the consulting veterinarians. The treatment protocols used were the same for both experimental groups.

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 >105.0°F (40.6°C); and no previous treatment history for BRD with no fever (NF). A diagnosis of 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 ≤104.9°F (40.5°C), and no previous treatment history for UF/BRD.

Relapses of UF or NF were defined as animals returned to their original feedlot pen following initial UF or initial NF therapy that were subsequently selected as "sick" by the pen-checkers. A diagnosis of relapse was made if there was a previous treatment history for UF or NF and 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, second, or third UF relapse). All animals relapsing subsequent to initial NF therapy were defined as NF relapses (i.e., first, second, or third NF relapse). The maximum number of UF or NF treatment regimes permitted for all animals on the study was four. 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 to be "chronics". Also, animals that were unsuitable to be returned to their designated feedlot pens, based on subjective appraisal of the attitude and appearance of each animal, were deemed to be chronics. Chronics that did not die during the study were defined as wastage. All other diseases were treated as per a standard feedlot protocol provided by the consulting veterinarians. All animal health events, including treatment date, presumptive diagnosis, drug usage and dosage, were recorded on the chute-side computer system (FHARM). All animals that died during the study were necropsied by the attending feedlot veterinarian, and cause of death was based on the finding of the gross postmortem examination.

Marketing

The animals were sold as per standard feedlot marketing procedures whereby the feedlot manager, based on visual appraisal and/or weight data, determined that a specific number of loads were ready for sale in each pen. The animals were scheduled for harvest and transported to the packing plant.[s] The same numbers of animals from each experimental group within a replicate were shipped to the same packing plant on the same day.

Data Collection and Management

At processing, data for the baseline variables initial weight, hip height (inches) and sex (steer or bull) were measured for each animal to assess the homogeneity of the animals in each experimental group. These data were subsequently entered into a spreadsheet program[t] where the average initial weight, average hip height and percent steers were calculated for each pen. The ancillary production variables, harvest weight, weight gain, carcass weight, dressing percentage, DOF and daily dry matter intake (DDMI), were calculated for each pen (Table 1).

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, BRD mortality, histophilosis mortality, arthritis mortality, metabolic mortality and miscellaneous mortality were calculated for each pen (Table 1).

The feedlot performance variables, average daily gain (ADG) and dry matter intake-to-gain ratio (DM:G), were calculated for each pen (Table 1). The feedlot performance variables were calculated by two methods: the live-weight basis method utilized the live weights obtained at the time of sale, and the carcass-weight basis method utilized the hot carcass weights obtained from the packing plant.

The quality grade (QG) and yield grade (YG) of each carcass were collected at harvest. With respect to QG, the proportions of carcasses grading Canada Prime, Canada AAA, Canada AA, Canada A, B4 (dark red rib eye) and E (pronounced masculinity) were calculated for each pen. With respect to 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.

Statistical Analysis

Data were analyzed using an analytical software program.[u] The baseline, ancillary production, feedlot performance and carcass characteristic variables were compared between the experimental groups using least squares analysis of variance for replicate and experimental group effects.[30] Baseline variables were tested as covariates of the performance variables. Those covari-

Table 1. Ancillary production, animal health and feedlot performance variable calculation formulas used in a study comparing two *Mannheimia haemolytica* immunization programs in feedlot calves.

Variable		Definition
		Ancillary Production
Harvest Weight	=	(total harvest weight divided by the number of animals harvested)
Weight Gain	=	(average harvest weight minus average initial weight)
Carcass Weight	=	(total carcass weight divided by the number of carcasses)
Dressing Percentage	=	(total carcass weight divided by total harvest weight x 100%)
Days-on-Feed (DOF)	=	(average harvest date minus average allocation date)
Daily Dry Matter Intake (DDMI)	=	(total dry matter fed (100% dry matter basis) divided by the number of animal days)
		Animal Health
Initial UF Treatment Rate	=	(number of animals initially treated for UF divided by the number of animals allocated) x 100%
First UF Relapse Rate	=	(number of first UF relapses divided by the number of animals initially treated for UF) x 100%
Initial NF Treatment Rate	=	(number of animals initially treated for NF divided by the number of animals allocated) x 100%
First NF Relapse Rate	=	(number of first NF relapses divided by the number of animals initially treated for NF) x 100%
Overall Chronicity Rate	=	(number of animals designated as chronic divided by the number of animals allocated) x 100%
Overall Wastage Rate	=	(number of animals designated as chronic that did not die divided by the number of animals allocated) x 100%
Overall Mortality Rate	=	(number of mortalities due to all causes divided by the number of animals allocated) x 100%
BRD Mortality Rate	=	(number of mortalities due to BRD divided by the number of animals allocated) x 100%
Histophilosis Mortality Rate	=	(number of mortalities due to histophilosis divided by the number of animals allocated) x 100%
Arthritis Mortality Rate	=	(number of mortalities due to arthritis divided by the number of animals allocated) x 100%
Metabolic Mortality Rate	=	(number of mortalities due to metabolic disease divided by the number of animals allocated) x 100%
Miscellaneous Mortality Rate	=	(number of mortalities due to causes other than BRD, histophilosis, arthritis, disease or metabolic divided by the number of animals allocated) x 100%
		Feedlot Performance
Average Daily Gain (ADG) Live Weight Basis	=	((total net slaughter weight plus total weight of animals shipped for salvage slaughter plus total weight of animals that died minus total initial weight) divided by the number of animal days)
ADG Carcass Weight Basis	=	(((total carcass weight divided by a fixed dressing percentage for each packing plant) plus total weight of animals shipped for salvage slaughter plus total weight of animals that died minus total initial weight) divided by the number of animal days))
Dry Matter Intake-to-Gain Ratio (DM:G) Live Weight Basis	=	(Daily Dry Matter Intake (DDMI) divided by ADG Live Weight Basis)
DM:G Carcass Weight Basis	=	(DDMI divided by ADG Carcass Weight Basis)

1. UF is undifferentiated fever and NF is no fever.
2. BRD is bovine respiratory disease.
3. Histophilosis is disease due to *Histophilus somni* infection.

ates with significant ($P<0.05$) effects were included in the final model used for comparison of each variable between the experimental groups as appropriate.[26] 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.[19,20]

Economic Analysis

The relative cost-effectiveness of the experimental groups was calculated using a computer spreadsheet program[t] that simulates all economic aspects of feedlot production.[6,10,27,28] In the economic model, the initial weight (655 lb; 297.1 kg), final weight (1,425 lb; 646.4 kg), feeder price ($120 CDN/100 lb BW), slaughter price, processing cost, ration cost, yardage rate and interest rate were fixed for both experimental groups. The costs of the *Mannheimia haemolytica* (+/- *Pasteurella multocida*) immunization programs used for each experimental group in the economic analysis were $1.91 CDN/animal and $3.46/animal in the PSQ and PHM-1 groups, respectively. Outcome variables describing the animal health, feedlot performance (carcass-weight basis ADG and carcass-weight basis DM:G), and carcass characteristics of each experimental group were incorporated into the model when significant ($P<0.05$) differences existed between the experimental groups. When there were no significant ($P\geq0.05$) differences between the experimental groups, the animal health, feedlot performance and carcass characteristics of the PHM-1 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/NF therapy were $26.95 CDN, $2.24 CDN and $20.53 CDN for each florfenicol,[v] oxytetracycline[w] and enrofloxacin[x] treatment regime, respectively. The cost of wastage was one-half of purchase cost ($393 CDN/wastage occurrence). The interest rate used in the analysis was 5.0%/annum. The discount for YG Canada 3 carcasses was $-3.00 CDN/100 lb ($-6.60 CDN/100 kg) carcass weight. Sensitivity analyses were performed for outcome variables that were significantly ($P<0.05$) different between the experimental groups to evaluate the effects of changes in input values on the economic analysis (Table 2).

Results

One animal in the PSQ group and two animals in the PHM-1 group were diagnosed using IHC testing of postmortem ear-skin biopsies as PI with BVD virus. As a result, the prevalence of PI animals in this study was at least 0.06% (3/5,128). The prevalence rate of PI animals in the study population was likely higher than this estimate because the number of PI animals that survived to slaughter was unknown.

The pen-based summary statistics for the baseline variables are presented in Table 3. The experimental groups were considered homogenous ($P\geq0.05$) with respect to average initial weight, average hip height and percentage of steers in each pen of animals.

The ancillary production data summary is presented in Table 4. There were no significant differences ($P\geq0.05$) in harvest weight, weight gain, carcass weight, dressing percentage, days-on-feed, or daily dry matter intake between the experimental groups.

The morbidity and mortality data summaries are presented in Tables 5 and 6, respectively. The first UF relapse, overall chronicity and overall wastage rates were significantly ($P<0.05$) lower in the PSQ group as compared to the PHM-1 group. There were no significant ($P\geq0.05$) differences in initial UF treatment, initial NF treatment, or first NF relapse rates between the experimental groups. With respect to mortality, there were no significant ($P\geq0.05$) differences in overall mortality, bovine respiratory disease mortality, histophilosis mortality, metabolic mortality, arthritis mortality, or miscellaneous mortality between the experimental groups.

The feedlot performance variables are summarized in Table 7. On both live-weight basis and carcass-weight basis, there were no significant ($P>0.05$) differences in ADG or DM:G between the experimental groups.

Table 2. Economic model input values and sensitivity analysis from a study comparing two *Mannheimia haemolytica* immunization programs in feedlot calves.

Description	Unit	Input value	Change evaluated in sensitivity analysis	Economic impact in PSQ vs PHM-1
First UF relapse treatment cost	$/animal	$20.53	$1.00	$0.01
Wastage cost	$/animal	$393.00	$100.00	$0.82
Yield Grade Canada 3 discount	$/100 lb carcass weight	-$3.00	$1.00	$0.31

1. PSQ is Presponse® SQ (Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario). There were 10 pens and 2,564 animals in the PSQ group.
2. PHM-1 is Pulmo-guard™ PHM-1 (Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario). There were 10 pens and 2,564 animals in the PHM-1 group.
3. UF is Undifferentiated Fever.
4. All economic impact values are expressed in $CDN/animal and should be interpreted as the effect on the economic analysis that is associated with the input value changes evaluated in the sensitivity analysis.

Table 3. Baseline data summary from a study comparing two *Mannheimia haemolytica* immunization programs in feedlot calves.

	Experimental group			
Baseline variable	PSQ	PHM-1	Standard error	*P*-value
Initial weight (lb)	653.4	656.2	± 1.1	0.096
Hip height (inches)	44.00	44.07	± 0.02	0.058
Steers (%)	99.38	99.45	± 0.09	0.614

1. PSQ is Presponse® SQ (Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario). There were 10 pens and 2,564 animals in the PSQ group.
2. PHM-1 is Pulmo-guard™ PHM-1 (Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario). There were 10 pens and 2,564 animals in the PHM-1 group.
3. 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.
4. Hip height is the average hip height of the animals in each pen.
5. Steers is the average proportion of steers in each pens.

Table 4. Ancillary production data summary from a study comparing two *Mannheimia haemolytica* immunization programs in feedlot calves.

	Experimental group			
Ancillary production variable	PSQ	PHM-1	Standard error	*P*-value
Harvest weight (lb)	1,423.3	1,427.5	± 3.8	0.462
Weight gain (lb)	769.9	771.2	± 3.3	0.774
Carcass weight (lb)	869.2	871.5	± 1.8	0.416
Dressing percentage	61.08	61.05	± 0.08	0.826
Days-on-feed (day)	229.6	229.5	± 0.1	0.517
Daily dry matter intake (lb/animal/day)	19.57	19.38	± 0.08	0.123

1. PSQ is Presponse® SQ (Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario). There were 10 pens and 2,564 animals in the PSQ group.
2. PHM-1 is Pulmo-guard™ PHM-1 (Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario). There were 10 pens and 2,564 animals in the PHM-1 group.
3. Harvest weight for each pen was calculated as the total shrunk live weight obtained prior to harvest divided by the number of animals sold and represents the average live weight of animals sold for regular harvest.
4. Weight gain for each pen was calculated as the average harvest weight minus the average initial weight and represents the average weight gain of animals sold for regular harvest.
5. Carcass weight for each pen was calculated as the total carcass weight obtained at harvest divided by the number of animals sold and represents the average carcass weight of animals sold for regular harvest.
6. Dressing percentage for each pen was calculated as the total carcass weight obtained at harvest divided by the total shrunk live weight obtained prior to harvest and represents the average dressing percentage of animals sold for regular harvest.
7. Days-on-feed for each pen was calculated as the average harvest date minus the average allocation date and represents the average number of days-on-feed of animals sold for regular harvest.
8. Daily dry matter intake for each pen was calculated as the total quantity of feed consumed (100% dry matter basis) divided by the number of cattle days and represents the pounds of feed consumed per animal per day.

The carcass grading data is presented in Table 8. The proportion of carcasses grading YG Canada 3 was significantly ($P<0.05$) higher in the PSQ group as compared to the PHM-1 group. There were no significant ($P\geq0.05$) differences between the experimental groups in the other carcass characteristic variables evaluated in the study.

In the economic analysis, there was an advantage of $4.06 CDN/animal in the PSQ group as compared to the PHM-1 group due to lower first UF relapse and

Table 5. Morbidity data from a study comparing two *Mannheimia haemolytica* immunization programs in feedlot calves.

	Experimental group				
Morbidity variable	PSQ	PHM-1	Relative risk	95% CI	*P*-value
Initial UF treatment	285 (11.12)	325 (12.68)	0.88	0.76 - 1.02	0.106
First UF relapse	44 (15.44)	75 (23.08)	0.67	0.46 - 0.99	0.042
Initial NF treatment	181 (7.06)	194 (7.57)	0.93	0.79 - 1.11	0.422
First NF relapse	52 (28.73)	47 (24.23)	1.14	0.82 - 1.64	0.525
Overall chronicity	38 (1.48)	64 (2.50)	0.59	0.40 - 0.88	0.011
Overall wastage	25 (0.98)	46 (1.79)	0.54	0.33 - 0.87	0.014

1. PSQ is Presponse® SQ (Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario). There were 10 pens and 2,564 animals in the PSQ group.
2. PHM-1 is Pulmo-guard™ PHM-1 (Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario). There were 10 pens and 2,564 animals in the PHM-1 group.
3. UF is undifferentiated fever.
4. NF is no fever.
5. Relative risk is the ratio of the rate of disease in the PSQ group divided by the rate of the disease in the PHM-1 group.
6. 95% CI is the 95% confidence interval 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 the confidence intervals. When convergence of the confidence interval could not be attained using the maximized likelihood function, asymptotic normality was used to calculate the confidence intervals.
7. Numbers in parentheses are percentages.

Table 6. Mortality data from a study comparing two *Mannheimia haemolytica* immunization programs in feedlot calves.

	Experimental group				
Morbidity variable	PSQ	PHM-1	Relative risk	95% CI	*P*-value
Overall mortality	55 (2.15)	64 (2.50)	0.86	0.60 - 1.22	0.411
BRD mortality	23 (0.90)	26 (1.01)	0.88	0.50 - 1.54	0.669
Histophilosis mortality	5 (0.20)	3 (0.12)	1.67	0.40 - 6.97	0.484
Arthritis mortality	2 (0.08)	6 (0.23)	0.33	0.07 - 1.65	0.179
Metabolic mortality	9 (0.35)	11 (0.43)	0.82	0.34 - 1.97	0.655
Miscellaneous mortality	16 (0.62)	18 (0.70)	0.89	0.57 - 1.39	0.606

1. PSQ is Presponse® SQ (Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario). There were 10 pens and 2,564 animals in the PSQ group.
2. PHM-1 is Pulmo-guard™ PHM-1 (Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario). There were 10 pens and 2,564 animals in the PHM-1 group.
3. Relative risk is the ratio of the rate of disease in the PSQ group divided by the rate of the disease in the PHM-1 group.
4. 95% CI is the 95% confidence interval 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 the confidence intervals. When convergence of the confidence interval could not be attained using the maximized likelihood function, asymptotic normality was used to calculate the confidence intervals.
5. Numbers in parentheses are percentages.
6. Refer to Table 1 for definitions of variables.

Table 7. Performance data summary from a study comparing two *Mannheimia haemolytica* immunization programs in feedlot calves.

	Experimental group			
Performance variable	PSQ	PHM-1	Standard Error	*P*-value
Average Daily Gain				
Live-weight basis	3.33	3.33	± 0.01	0.924
Carcass-weight basis	3.44	3.44	± 0.01	0.696
Dry matter intake-to-gain ratio				
Live-weight basis	5.88	5.82	± 0.02	0.070
Carcass-weight basis	5.69	5.64	± 0.02	0.143

1. PSQ is Presponse® SQ (Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario). There were 10 pens and 2,564 animals in the PSQ group.
2. PHM-1 is Pulmo-guard™ PHM-1 (Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario). There were 10 pens and 2,564 animals in the PHM-1 group.
3. Average daily gain (ADG) is the average number of pounds gained per day during the feeding period. The effect of animals that died has been removed from the ADG values.
4. Dry matter intake-to-gain ratio (DM:G) is a ratio of the pounds of feed (expressed on a 100% dry matter basis) necessary for 1one pound of gain. The effect of animals that died has been removed from the DM:G values.
5. Live-weight basis values were calculated using shrunk live weights obtained prior to slaughter.
6. Carcass-weight basis values were calculated using carcass weights obtained at slaughter, converted to live weights using a fixed dressing percentage of 60.0%.

Table 8. Carcass grading data summary from a study comparing two *Mannheimia haemolytica* immunization programs in feedlot calves.

	Experimental group			
Carcass grading variable	PSQ	PHM-1	Standard Error	*P*-value
Yield Grade				
Canada 1	30.23	30.79	± 0.79	0.627
Canada 2	38.23	41.35	± 1.27	0.115
Canada 3	31.54	27.86	± 0.83	0.012
Quality Grade				
Canada Prime	1.44	0.78	± 0.28	0.127
Canada AAA	61.79	61.07	± 1.25	0.693
Canada AA	36.30	37.65	± 1.42	0.516
Canada A	0.27	0.37	± 0.14	0.634
B4	0.20	0.09	± 0.10	0.425
E	0.00	0.04	± 0.03	0.343

1. PSQ is Presponse® SQ (Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario). There were 10 pens and 2,564 animals in the PSQ group.
2. PHM-1 is Pulmo-guard™ PHM-1 (Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario). There were 10 pens and 2,564 animals in the PHM-1 group.
3. Yield Grade (YG) Canada 1 is the proportion of carcasses within a pen that graded YG Canada 1.
4. Yield Grade Canada 2 is the proportion of carcasses within a pen that graded YG Canada 2.
5. Yield Grade Canada 3 is the proportion of carcasses within a pen that graded YG Canada 3.
6. Quality Grade (QG) Canada Prime is the proportion of carcasses within a pen that graded QG Canada Prime.
7. Quality Grade Canada AAA is the proportion of carcasses within a pen that graded QG Canada AAA.
8. Quality Grade Canada AA is the proportion of carcasses within a pen that graded QG Canada AA.
9. Quality Grade Canada A is the proportion of carcasses within a pen that graded QG Canada A.
10. Quality Grade B4 is the proportion of carcasses within a pen that graded QG B4 (dark red rib eye).
11. Quality Grade E is the proportion of carcasses within a pen that graded QG E (pronounced masculinity).
12. All numbers are expressed as percentages.

overall wastage rates and a lower *M. haemolytica* immunization cost, even though there was a higher proportion of YG Canada 3 carcasses in the PSQ group as compared to the PHM-1 group (Table 9).

Discussion

In this study, using PSQ upon arrival at the feedlot to vaccinate cattle at high risk of developing UF/BRD resulted in improved animal health outcomes as compared to using PHM-1. This is evidenced by significant reductions in the first UF relapse, overall chronicity and overall wastage rates. PSQ is less expensive than PHM-1 and this contributes to the cost-effectiveness of PSQ. However, even if the price of the two vaccines is similar, PSQ would still be more cost-effective than PHM-1. In addition, if the cost of overall wastage used in the economic modeling is reduced by 50%, PSQ would remain more cost-effective than PHM-1.

The exact reason for the better health outcome observed in feedlot calves that received PSQ in this study is unknown. It is possible that this observation is due to the fact that the *M. haemolytica* component of PSQ induces a protective immunity that is superior to the immunity induced by the *M. haemolytica* component of PHM-1. However, there are two major differences between these vaccines that should also be considered when trying to explain the results observed in this study. The first difference is that PSQ contains only a *M. haemolytica* component while PHM-1 contains both a *M. haemolytica* component and a *P. multocida* component. Contrary to what one might expect, the inclusion of a *P. multocida* component in PHM-1 did not improve animal health outcomes as compared to PSQ. It is possible that exposure to *P. multocida* did not occur in the study population; however, based on the size and diversity of the feedlot populations studied and the authors' experience with estimating *P. multocida* exposure using bacterial culture and/or other serology, a lack of exposure to *P. multocida* in large feedlot populations seems unlikely. Perhaps the role of *P. multocida* in the pathogenesis of BRD in feedlot cattle is overestimated, or induction of immunity to *P. multocida* resulted in a negative effect on animal health outcomes. Further studies to investigate the role and significance of *P. multocida* in the pathogenesis of BRD are warranted.

The second difference between the two vaccines is that PSQ contains an adjuvant[y] while PHM-1 does not. It is possible that the use of an adjuvant contributed to the improved animal health outcome in calves that received PSQ, but this is difficult to confirm. A clinical trial comparing two identical vaccines, one with and one without the adjuvant, in commercial field trials using economically important outcome values would be needed to critically investigate the exact effect of the adjuvant.

In this study, there was a higher proportion of carcasses grading YG Canada 3 in the PSQ group, but the reason for this is unknown. However, it is possible that this is the result of type I experimental error, where an observed difference is attributed to an experimental group effect when it is actually due to chance. Further research is needed to determine if this observation is truly a result of using PSQ or occurred due to random chance.

The economic analysis model used in this study was conservative. It evaluated the economic impact of the average (point estimate) differences in animal health, feedlot performance and carcass characteristic outcome variables between the experimental groups.

Table 9. Economic analysis summary from a study comparing two *Mannheimia haemolytica* immunization programs in feedlot calves.

Description	Economic impact in PSQ vs PHM-1
First undifferentiated fever relapse	$0.20
Overall wastage	$3.23
Yield Grade Canada 3	-$0.94
Immunization program cost	$1.57
Total economic advantage for PSQ	$4.06

1. PSQ is Presponse® SQ (Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario). There were 10 pens and 2,564 animals in the PSQ group.
2. PHM-1 is Pulmo-guard™ PHM-1 (Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario). There were 10 pens and 2,564 animals in the PHM-1 group.
3. All values are expressed in $CDN/animal and represent the economic impact of the observed significant ($P<0.05$) differences between the experimental groups.

Differences in outcome variables between the groups were only evaluated if the probability of chance alone in producing the difference observed was below a specified level of $P<0.05$. This method was selected because it is conservative, straightforward, directly ascribes an economic effect to a significant ($P<0.05$) difference in a biologic outcome variable and presents an average economic effect that is easy for producers to understand and interpret. 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. In addition, it does not consider a range of values for the biologic outcome variables evaluated in the model. The latter observation is often put forth as a limitation of the approach used because it does not provide a range of economic impacts for each biologic outcome variable. However, from a practical viewpoint, this limitation is a theoretical one that is very important when statistical analyses are not used to "filter" the inclusion/exclusion of biologic outcome variables in an economic analysis model and much less important when a conservative approach to the inclusion of biologic outcome variables in an economic analysis is used.

This study was designed to have sufficient experimental power to detect differences in ADG or DM:G of 2-3%, the magnitude of which was deemed by the investigators to be economically important to detect. The study results show no difference in ADG and only a 1% difference in DM:G between the experimental groups. Therefore, a lack of experimental power to detect 2-3% differences in feedlot performance between the groups was not an issue in this study. Moreover, the results demonstrate that there was obviously sufficient experimental power to detect differences in overall chronicity and wastage between the experimental groups.

Conclusions

Based on the results of this study, it is more cost effective to use Presponse SQ than Pulmo-guard PHM-1 in feedlot calves at high risk of developing bovine respiratory disease in western Canada. This was evidenced by significant improvement in the first UF relapse, overall chronicity and overall wastage rates. However, feedlot cattle in the Presponse SQ group had a higher proportion of carcasses grading YG Canada 3 ($P<0.05$) when compared to the Pulmo-guard PHM-1 group. In the economic analysis, there was an advantage of $4.06 CDN/animal in the Presponse SQ group when compared to the Pulmo-guard PHM-1 group. The exact reason for the differences in animal health and carcass characteristic outcome variables between the two vaccines remains unknown.

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Endnotes

[a]Pulmo-guard™ PHM-1, Boehringer Ingelheim (Canada) Ltd., Burlington, Ontario
[b]Presponse® SQ, Wyeth Animal Health, Division of Wyeth Canada, Guelph, Ontario
[c]Feedlot Health Animal Record Management© (FHARM), Feedlot Health Management Services Ltd., Okotoks, Alberta
[d]Pyramid® FP 5, Wyeth Animal Health, Division of Wyeth Canada
[e]Ultrabac® 7/Somubac®, Pfizer Animal Health, Pfizer Canada Inc., Kirkland, Quebec
[f]Tetradure® LA-300, Merial Canada Inc., Baie D'Urfé, Quebec
[g]Synovex® Choice, Wyeth Animal Health, Division of Wyeth Canada
[h]Unimectrin® Pour-On, Merial Canada Inc.
[i]Pyramid® FP 4, Wyeth Animal Health, Division of Wyeth Canada
[j]Synovex® Choice
[k]Bovi-Shield® IBR-PI3, Pfizer Animal Health, Pfizer Canada Inc.
[l]Norwest Labs, Lethbridge, Alberta
[m]Prairie Diagnostic Services, Saskatoon, Saskatchewan
[n]Nutritional Requirements for Beef Cattle, National Research Council, 1996
[o]Aureomycin®, Alpharma Canada Corporation, Mississauga, Ontario
[p]Rumensin®, Elanco Animal Health, Division Eli Lilly Canada Inc., Guelph, Ontario
[q]Tylan®, Elanco Animal Health, Division Eli Lilly Canada Inc.
[r]Landmark Feeds Inc., Strathmore, Alberta
[s]Cargill Foods, High River, Alberta
[t]Microsoft® Office Excel 2003, Microsoft Corporation, Redmond, Washington
[u]SAS for Windows, Release 9.1, SAS Institute Inc., Cary, North Carolina
[v]Nuflor®, Schering-Plough Animal Health, Division of Schering Canada Inc., Pointe Claire, Quebec
[w]Oxymycine LA, Wyeth Animal Health, Division of Wyeth Canada Inc.

[x]Baytril® 100, Bayer Healthcare, Animal Health Division, Bayer Inc., Toronto, Ontario
[y]MetaStim®, Fort Dodge Animal Health, Wyeth Animal Health, Division of Wyeth Canada

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