PEER REVIEWED

A Comparison of Two Vaccines to Reduce Liver Abscesses in Natural-fed Beef Cattle

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Abstract

A blinded interventional clinical trial was conducted to evaluate the efficacy of two liver abscess vaccines in natural-fed beef cattle. Feedlot cattle (n = 1,307 head, initial body weight = 613 ± 71 lb; or 279 ± 32 kg) were randomly assigned to one of three vaccine treatments: no vaccine (control); vaccination with a *Fusobacterium necrophorum* bacterin (Fusogard®, Novartis Animal Health US, Inc, Greensboro, NC); or vaccination with an *Arcanobacterium pyogenes-Fusobacterium necrophorum* toxoid (Centurion™, Intervet/Schering-Plough Animal Health, DeSoto, KS). Cattle were fed a finishing diet consisting of 73% steam-flaked corn and 13% roughage (as-fed basis). At harvest, livers were scored using the Elanco Liver Scoring System. Incidence of liver abscesses (56%) and severe liver abscesses (39%) was relatively high in this study. Vaccine treatment did not affect incidence of liver abscesses or severe liver abscesses, nor did it affect liver abscess score. Initial body weight, 60-day body weight, 60-day average daily gain (ADG), total days-on-feed (DOF), hot carcass weight, yield grade, and quality grade were not different among vaccine treatments. Cattle with abscessed livers at harvest tended to have lower 60-day ADG than those without abscesses. Presence of liver abscesses increased (P=0.02) total DOF, but only by two days. Presence of severe liver abscesses was associated with reduced (P<0.01) hot carcass weight, and more cattle that graded USDA Select rather than USDA Choice (P=0.01).

Keywords: feedlot, liver, abscess, *Fusobacterium, Arcanobacterium*

Résumé

Un essai clinique d'intervention à l'aveugle a évalué l'efficacité de deux vaccins contre les abcès du foie chez les bovins nourris avec des aliments naturels. En parc d'engraissement, on a réparti des bovins (n = 1 307 têtes, d'un poids corporel initial = 613 ± 71 lb, ou 279 ± 32 kg), au hasard, dans trois groupes de vaccination différents : aucun vaccin (témoins), un vaccin à la bactérine *Fusobacterium necrophorum* (Fusogard®, de Novartis Animal Health US, Inc., à Greensboro, NC) et un vaccin au toxoïde *Arcanobacterium pyogenes-Fusobacterium necrophorum* (Centurion™, de Schering-Plough Animal Health, à DeSoto, KS). Les bovins ont consommé une ration d'engraissement comprenant du maïs floconné à la vapeur et de fourrage, dans une proportion de 73 % et de 13 % (tel que servi), respectivement. À la récolte, la sévérité des abcès du foie a été cotée suivant le système *Elanco*. L'incidence des abcès du foie en général (56 %) et des abcès du foie graves (39 %) s'est avérée relativement élevée dans cette étude. Les traitements de vaccination n'ont pas eu d'impact sur le nombre d'abcès au foie en général et d'abcès au foie graves, ni sur la cote de sévérité de ces abcès. La vaccination n'a pas non plus donné de réponses différentes en ce qui a trait aux paramètres suivants : poids corporel initial, poids corporel à 60 jours, gain moyen quotidien (GMQ) à 60 jours, nombre total de jours à la ration (DOF), poids de la carcasse chaude, classement de rendement ou classement de qualité. Les bovins montrant des abcès à la récolte ont eu tendance à avoir un GMQ à 60 jours inférieur. La présence d'abcès au foie en général a augmenté (P = 0,02) le DOF, mais seulement de deux jours. La présence d'abcès graves au foie était associée à un plus faible poids de la carcasse chaude (P<0,01) et à un déclassement accentué (P = 0,01) vers la classe *USDA Select* au détriment de la classe *USDA Choice*.

Introduction

Liver abscesses are a common sequela of feeding high-concentrate diets to cattle.[1,15] Presence of liver abscesses can result in reduced average daily gain (ADG) and feed efficiency, as well as require additional carcass trimming if the abscesses adhere to the diaphragm and adjacent organs, thereby reducing carcass yield.[3,7] Etiological agents frequently isolated from liver abscesses include *Fusobacterium necrophorum* (formerly *Sphaerophorus necrophorus*) and *Arcanobacterium pyogenes* (formerly *Actinomyces pyogenes*).[9] Antimicrobials are frequently fed to finishing cattle to reduce the incidence of liver abscesses,[2,5,10] however, antibiotics and growth-promoting hormones are not allowed for use in natural beef programs.[13,14] A potential alternative control for liver abscesses is the use of vaccine, which is allowed in both organic and natural beef programs.[13,14]

Two commercial vaccines are labeled for control of liver abscess pathogens. The first is a bacterin approved to reduce the number and size of liver abscesses caused by *F. necrophorum* in healthy cattle over six months of age.[a] Previous reports suggest use of this vaccine reduces (P=0.05) severe liver abscesses in cattle fed a forage-based diet, but failed to elicit a similar response in cattle limit-fed a high concentrate diet.[4] The second vaccine contains an inactivated leukotoxin of *F. necrophorum* and *A. pyogenes* pyolysin.[b] Label indication for this vaccine is to aid in reduction of liver abscesses associated with *A. pyogenes* or *F. necrophorum*. In two studies, this toxoid reduced the incidence of liver abscesses in feedlot cattle by 48 and 38%.[6] This vaccine is no longer commercially available.

The objectives of this study were to 1) evaluate the efficacy of two commercial liver abscess vaccines for reducing liver abscesses at harvest in natural-fed finishing cattle, and 2) assess differences in animal performance and carcass traits in natural-fed finishing cattle with or without liver abscesses at harvest.

Materials and Methods

Scope of the study

Beef cattle raised under "natural" conditions, e.g. cattle that had never received an antibiotic or a growth-promoting hormone implant, were randomly allocated at feedlot arrival to one of three experimental groups. Treatment groups were commingled within pens, and cattle were followed from arrival-processing to harvest to compare the effect of two different liver abscess vaccines on the incidence and severity of liver abscesses, ADG, days-on-feed (DOF), and carcass traits to non-vaccinated control cattle. Individual animal was the experimental unit. Data were analyzed to determine whether differences were due to vaccine effect or to random chance. Statistical significance was designated as P<0.05.

Facilities

The study was conducted in a commercial feedlot in central Kansas with a one-time capacity of 10,000 cattle. The feedlot had outdoor pens with pipe and cable fencing at the back and separating the cattle from adjacent pens on each side. Concrete feed bunks were located at the front of the pens. Water was provided *ad libitum* in commercially available automatic watering tanks.

Cattle

A total of 1,307 steer and heifer feeder cattle weighing 613 ± 71 lb (279 ± 32 kg) were received from various farms and ranches to be fed in a natural feeding program. Cattle were placed on study from November 29 to December 22, 2006. Upon arrival, cattle were assigned to a lot number, which identified cattle based on owner and source of the cattle. Each lot contained 200 to 500 feeder cattle; this lot number was the only variable to account for variation due to breed, age, and gender.

Within 48 hours of arrival at the feedlot, calves were moved through a chute with scales and processed as follows:

- A uniquely numbered tag was placed in the ear of each calf. Tags were color-coded to identify animals given similar experimental treatments.
- Calves were individually weighed and weights were recorded.
- A modified-live infectious bovine rhinotracheitis (IBR), bovine viral diarrhea (BVD types 1 and 2), parainfluenza-3, bovine respiratory syncytial virus vaccine[a] was administered according to label instructions.
- A 7-way clostridial bacterin-toxoid[b] was administered according to label instructions.
- Topical ivermectin[c] and fenbendazole[d] suspension were administered at label dosage for control of internal and external parasites.
- Ears were examined for the presence of growth-promoting implants. Growth-promoting implants are not allowed in the natural beef program.
- Based upon a randomization table, animals were either administered one of two vaccines labeled for reduction of liver abscesses, or served as a non-vaccinated control

At 60 DOF, all cattle were taken through the processing facility, where cattle were weighed individually and body weights were recorded. Cattle in the group vaccinated with the *F. necrophorum* bacterin were re-vaccinated with the same bacterin. Cattle in the other two study groups were not sham vaccinated.

Study design

During processing, cattle were randomly assigned to one of three experimental treatments: control (no vaccine); vaccinated with a *Fusobacterium necrophorum* bacterin[e] (FNB); or vaccinated with an *Arcanobacterium pyogenes-Fusobacterium necrophorum* toxoid[f] (APFNT). Both products were administered as per label instructions.

Using a computer-generated randomization table, cattle were assigned to treatment in a randomized block design. Every set of five animals was administered a single treatment, so that each treatment was equally represented in 15 consecutive animals. Cattle were not assigned to pens based on treatment; instead, every pen contained equal numbers of cattle from each experimental treatment. Pen capacities ranged from 70 to 200 head.

Feeding

Cattle were adapted to increasing levels of energy in the diet by using a series of four step-up diets. The finishing diet consisted of (as-fed basis) 73% steam-flaked corn, 9% wet distillers grains, 6% sorghum silage, 4% alfalfa hay, 3% soybean straw, and 5% supplement. Ionophores and antimicrobials, such as tylosin and chlortetracycline, were not included in the diet in order to meet the standards of a specific natural beef program prior to the release of new USDA standards.[14]

Cattle harvest and liver abscess scoring

Cattle on study were evaluated on a weekly basis by feedlot management to select cattle for harvest during that week. At the commercial harvest facility, plant employees collected hot carcass weights (HCW), while USDA graders determined USDA yield grade and USDA quality grade. Masked members of the research team scored livers based on visual evaluation by team members; palpation of livers and evaluation of cut surface was done by USDA inspectors. Liver scores were assigned using the Elanco Liver Scoring System[g]: 0, no abscesses evident; A-, one or two small abscesses or scars; A, two-to-four well-organized abscesses less than one-inch (2.5-cm) in diameter; or A+, one or more large, active abscesses grater than one-inch (2.5-cm) in diameter with inflammation into hepatic parenchyma. No samples were collected for culture or histopathology.

Statistical analysis

Statistical analysis was performed by a member of the research team (JTF) blinded to treatment allocation and ear tag color assignments. Individual animal was the experimental unit. For each animal in the study, a binomial distribution of outcomes was used for liver abscess presence (liver abscess score 0, A-, A, or A+) and severe liver abscess presence (liver abscess score 0 or A- vs A or A+). These data were analyzed using logistic regression in PROC GLIMMIX of SAS.[h] Statistical models included vaccine treatment, feedlot number, and the two-way interaction as fixed effects and total DOF as a random effect. A similar model was used to analyze liver abscess scores with the exception of utilizing an ordinal, multivariate distribution of outcomes.

Arrival body weight (BW), 60-day BW, 60-day ADG, and total DOF were analyzed using general linear mixed models (PROC MIXED of SAS[d]). Three separate models were used to assess differences in liver abscess presence, severe liver abscess presence (A or A+), and liver abscess scores. Treatment and feedlot number were included as fixed effects in all models, and two- and three-way interactions were included initially and then removed to create final models if $P>0.15$. Hot carcass weight (HCW) and USDA yield grade were analyzed in a similar manner except total DOF was included as a random effect. For USDA quality grade, a similar three model system was used with treatment and feedlot number included as fixed effects with all two- and three-way interactions and total DOF as a random effect and modeled as an ordinal, multivariate distribution of outcomes (PROC GLIMMIX of SAS). If no significant interactions were observed, univariate models were constructed to evaluate associations between USDA quality grade and treatment, liver abscess presence, severe liver abscess presence, and liver abscess score using PROC FREQ of SAS. Associations between USDA quality grade and variables with $P<0.10$ from univariate analyses were further characterized by analyzing USDA quality grade as three dummy variables, each with a binomial distribution of outcomes (i.e. Prime, yes or no; Choice, yes or no; Select, yes or no) for each animal. This procedure was performed with PROC GENMOD of SAS.

Results

Of the 1,307 cattle that had liver abscess scores, 60-day BW were not recorded for 37 of the cattle. Hot carcass weight, USDA yield grade, and USDA quality grade were not collected from 116 cattle because of a computer malfunction at the harvest facility. Seven additional carcasses were graded as 'no rolls' and were also removed from analyses.

In total, 734 of 1,307 cattle (56%) had liver abscesses, and 515 of the 1,307 animals (39%) had severe liver abscesses (A or A+). Vaccine treatment did not impact the incidence of liver abscesses ($P=0.66$) or severe liver abscesses ($P=0.75$; Figure 1), nor did it impact liver abscess scores ($P=0.61$; Figure 2). Cattle within different lots had different ($P<0.01$) liver abscess rates, severe liver abscess rates, and liver abscess scores, but the interaction between lot and treatment was not significant ($P>0.30$) for any of these variables.

The effect of vaccine treatment and presence of liver abscesses at harvest on animal performance is shown in Table 1. Initial BW at enrollment (raw mean ± standard deviation = 613 ± 71 lb; 279 ± 32 kg), 60-day BW (795 ± 83 lb; 361 ± 38 kg), 60-day ADG (3.04 ± 1.1 lb; 1.38 ± 0.5 kg), total DOF (237 ± 20 days), and HCW (738 ± 63 lb; 335 ± 29 kg) were not affected ($P>0.10$) by vaccine treatment.

The presence of a liver abscess at harvest decreased ($P=0.02$) total DOF, and tended ($P=0.06$) to decrease

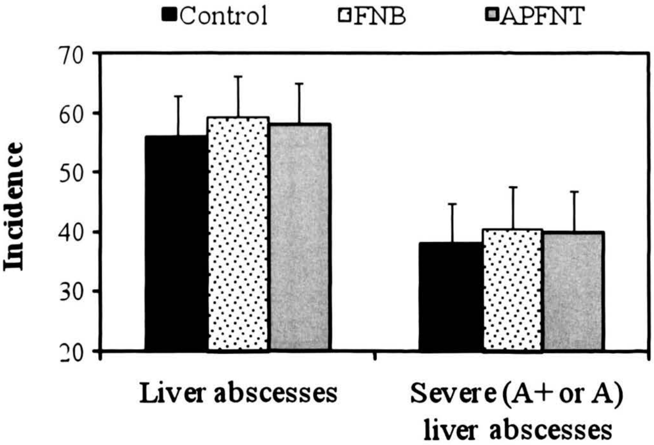

Figure 1. Incidence (and 95% confidence intervals) of liver abscesses and severe liver abscesses by vaccine treatment (control, vaccinated with Fusogard®, a *Fusobacterium necrophorum* bacterin (FNB), or vaccinated with Centurion™, an *Arcanobacterium pyogenes-Fusobacterium necrophorum* toxoid (APFNT).

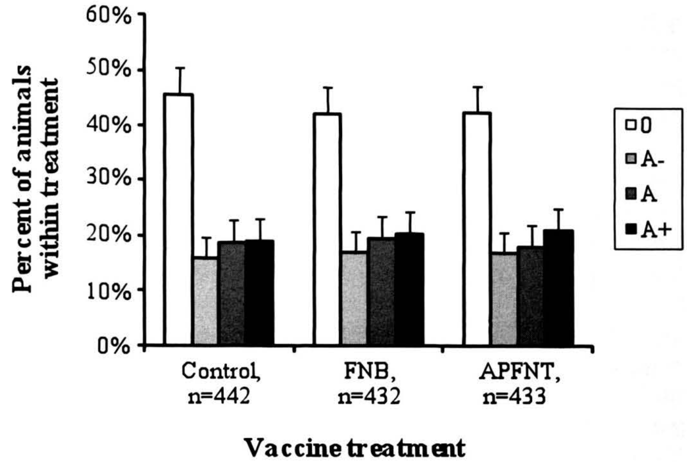

Figure 2. Distribution (and 95% confidence intervals) of liver abscess scores within vaccine treatments (control, vaccinated with Fusogard®, a *Fusobacterium necrophorum* bacterin (FNB), or vaccinated with Centurion™, an *Arcanobacterium pyogenes-Fusobacterium necrophorum* toxoid (APFNT).

Table 1. Effects of vaccine treatment, liver abscesses, and feedlot lot number on animal performance.[1]

	Vaccine treatment				Liver abscess			Lot number[2]
Outcome variable	Control[3] n = 442	FNB[4] n = 432	APFNT[5] n = 433	*P*-value	No n = 573	Yes n = 734	*P*-value	*P*-value
Initial body weight, lb[6]	615	616	612	0.67	615	614	0.90	<0.01
60-day body weight, lb	802	794	791	0.14	799	793	0.20	<0.01
60-day ADG, lb/day[7]	3.12	2.99	3.00	0.19	3.10	2.97	0.06	<0.01
Total days-on-feed	238	238	240	0.23	238[e]	240[f]	0.02	<0.01
Hot carcass weight, lb[8]	746	740	746	0.27	746	742	0.15	0.01

[1]Statistical model for this analysis included treatment (control, vaccination with *Fusobacterium necrophorum* bacterin (FNB), or vaccination with *Arcanobacterium pyogenes-Fusobacterium necrophorum* toxoid (APFNT), feedlot number, presence or absence of liver abscesses as fixed effects, any significant interactions, and total days-on-feed as a random effect for analyses of hot carcass weight. Numbers represent least-squares means from the statistical model.
[2] Identification of cattle group based upon the owner and source. Cattle from six lots were utilized in this study, and the lots contained between 200 and 500 animals.
[3] Control – no vaccine administered to control liver abscesses.
[4] FNB is Fusogard®, a *Fusobacterium necrophorum* bacterin, Novartis Animal Health US Inc, Greensboro, NC.
[5] APFNT is Centurion™, an *Arcanobacterium pyogenes-Fusobacterium necrophorum* toxoid, Intervet/Schering-Plough Animal Health, DeSoto, KS.
[6]Interaction between vaccine treatment and liver abscesses, P=0.04.
[7] Interaction between feedlot number and liver abscesses, P=0.03.
[8] Interaction between vaccine treatment and feedlot number, P=0.04.
[e,f] Least squares means not sharing a common superscript letter are different (P<0.05).

60-day ADG (Table 1). The vaccine treatment × liver abscess presence interaction was significant (P=0.04) for initial BW (data not shown). There was a vaccine treatment by lot interaction (P=0.04) for HCW. Presence of severe liver abscesses tended (P=0.09) to reduce total DOF, but not 60-day ADG (Table 2). Presence of severe liver abscesses reduced (P=0.01) HCW, while cattle with A+ liver abscesses had lower (P<0.05) HCW than cattle with either A- or no liver abscesses (Table 2).

Analysis of USDA yield grade (raw mean ± standard deviation = 2.74 ± 0.7) revealed that lot, and the interaction between lot and vaccine treatment, influenced USDA

Table 2. Effects of severe (A or A+) liver abscesses and liver abscess scores on animal performance.[1]

Outcome variable	Severe liver abscess			Liver abscess score			
	No n = 792	Yes n = 515	*P*-value	0 n = 573	A- n = 219	A n = 248	A+ n = 267
Initial body weight, lb	614	615	0.77	614	612	607	622
60-day body weight, lb	797	793	0.43	799	792	786	799
60-day ADG, lb/day	3.06	2.97	0.17	3.09	3.00	2.98	2.96
Total days-on-feed	238	240	0.09	238	240	239	240
Hot carcass weight, lb	746[f]	739[e]	0.01	746[f]	748[f]	742[e,f]	737[e]

[1]Statistical models included treatment, feedlot number, and either presence or absence of severe liver abscesses, or liver abscess score as fixed effects, any significant interactions, and total days-on-feed as a random effect for analyses of hot carcass weight. Numbers represent least-squares means from the statistical model.

[e,f]Least squares means not sharing a common superscript letter within abscess classification are different ($P<0.05$).

yield grades, but vaccine treatment, presence of liver abscesses, presence of severe liver abscesses, and liver abscess scores did not ($P>0.20$) affect yield grade (data not shown). Initial analysis (Figure 3) of USDA quality grades (Prime, n=39; Choice, n=897; Select, n=173) showed an association between quality grade and the presence of severe liver abscesses ($P=0.02$), and tended to show an association between quality grade and the presence of liver abscesses ($P=0.07$). There were differences between lots ($P<0.01$). No two- or three-way interactions were associated with USDA quality grades. As a result, univariate associations between USDA quality grades and liver abscess presence, severe liver abscess presence, liver abscess score, and vaccine treatment were assessed using chi-square tests. With the exception of vaccine treatment, all variables were associated ($P<0.05$) with USDA quality grade, therefore further analysis was conducted to determine specific differences between measures of liver abscessation and USDA quality grade (Figures 3 and 4). These results suggest that liver abscesses, either being present or increasing in severity, caused a decrease in the proportion of animals grading USDA Choice as compared to USDA Select.

Discussion

Liver abscesses in cattle at harvest result in losses in performance, as well as total carcass value. Conventional-fed cattle are fed antimicrobials to reduce the incidence of liver abscesses,[1,15] but they are not allowed for use in cattle in natural and organic programs. Consumers are attracted to natural beef for many reasons, including the prohibition of using growth-promoting implants, antimicrobials, and animal by-products during any time in the animal's life. In addition, many consumers perceive that naturally raised cattle are treated more humanely, and associate them with more environmentally friendly production practices.[8] Many of these factors are driving forces for demand of various beef products. Organic and natural beef production programs do allow vaccines, thus making them a crucial and logical choice for prevention of many diseases.[13,14]

Individual animal was the experimental unit in this study. Cattle from each treatment group were represented evenly through all pens of cattle in the study. Cattle from each treatment group were commingled within pens to decrease variation in feed delivery or ration deviations during the feeding program. No significant differences between vaccine treatments were found

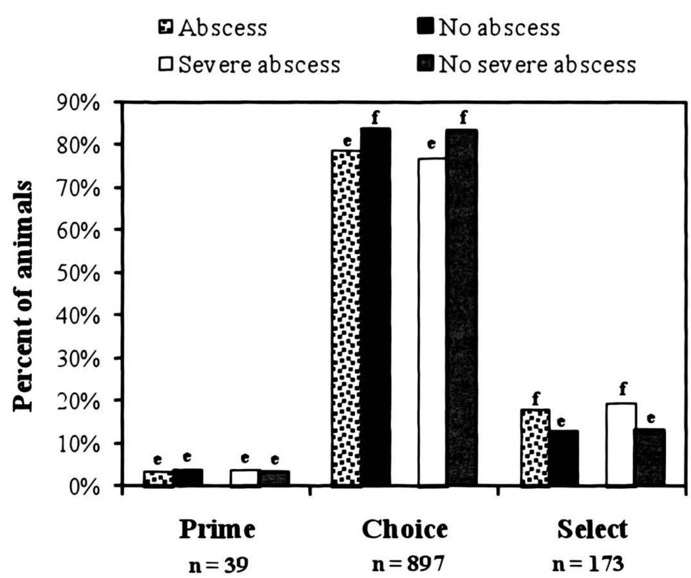

Figure 3. Presence or absence of liver abscesses (black-spotted and black bars respectively), and presence or absence of severe liver abscesses (grey-spotted and grey bars, respectively) in cattle grading USDA prime, choice and select. Bars with different letters (within USDA quality grade and liver abscess classification) are statistically different ($P<0.05$).

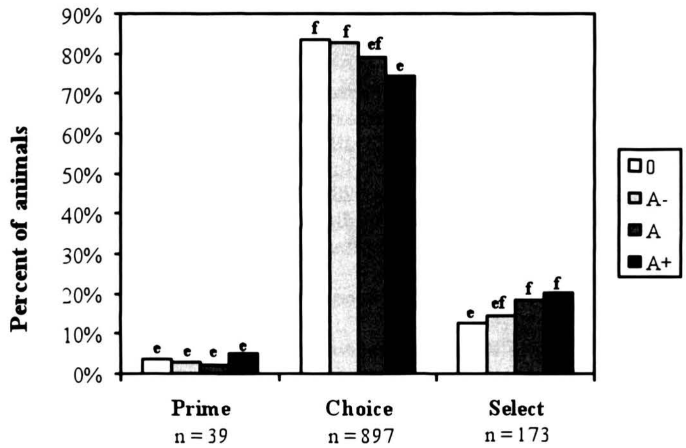

Figure 4. Distribution of liver abscess scores in cattle grading USDA prime, choice and select. Bars not sharing a common letter (within quality grade) are statistically different ($P \leq 0.05$).

for liver abscess incidence, abscess severity, or abscess scores. It was suggested previously that the protective effect of FNB vaccine may be inadequate to protect against challenge when cattle are limit-fed a high grain diet.[4] The liver abscess incidence and the percentage of severe liver abscesses were extremely high in this study compared to previous studies evaluating these two vaccines, where overall incidence was <30%.[4,6]

Liver abscesses in this study were not cultured to determine the causative organism(s), therefore the specific pathogen(s) was not defined. The objective of this study was to determine if these vaccines were efficacious in a commercial feedlot feeding natural cattle. Liver abscesses result when cattle are fed a high concentrate diet similar to the one utilized in this study.[1,15] In conventional feeding programs, feedlot diets include an ionophore and an antimicrobial effective against *F. necrophorum*, therefore a lower incidence of liver abscesses.[2,5,10]

There was a wide range in outcomes among cattle in different lots in this study, suggesting that genotype, phenotype, gender, and age of cattle being fed offers substantial variation in performance and carcass traits, as well as liver abscessation rate. Previous research has shown that the incidence of liver abscesses is greater in Holsteins than in beef breeds, and greater in steers than in heifers.[8,11] In both of these cases, a higher incidence of liver abscesses was associated with higher feed intake and more DOF.[9] In the current study, total DOF was greater (240 vs 238) for cattle with liver abscesses compared to those without abscesses, which is consistent with previous observations. Although the difference in DOF between cattle with and without liver abscesses was statistically significant in this study, two days difference in DOF in reality may not have a meaningful impact on cost of production. However, Brink *et al* reported cattle with abscessed livers have reduced feeding performance,[3] thus in some cases feeding to a common physiologic endpoint could result in a longer feeding period for cattle with liver abscesses.

In general, economic losses from liver abscesses result from reduced performance and carcass yield.[9] In the present study, there was a shift in the distribution of USDA quality grades due to liver abscesses and severity of liver abscesses (Figures 3 and 4), but there was no effect of liver abscesses on USDA yield grade. A previous study found that cattle vaccinated with APFNT and fed tylosin phosphate had improved USDA yield grade compared to non-vaccinated cattle fed tylosin phosphate; however, they did not find any significant association with USDA quality grade.[6] Montgomery *et al* reported no association between liver abscess scores and USDA yield grade or quality grade, but did observe lighter HCW in cattle with severe liver abscesses, which is consistent with our study.[7]

Conclusions

The use of liver abscess vaccines did not reduce incidence or severity of liver abscesses at harvest, nor did they affect performance or carcass traits. Cattle with liver abscesses required more total DOF to reach harvest weight compared to cattle without liver abscesses. Cattle with severe liver abscesses had lighter HCW than cattle without severe liver abscesses. The presence of liver abscesses and severe liver abscesses was associated with a lower percentage of carcasses grading USDA Choice compared to carcasses from cattle without liver abscesses. In this study, vaccines did not alter liver abscess rates or improve the economic outcome for cattle enrolled in natural beef programs.

Acknowledgements

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Endnotes

[a]Arsenal 4.1, Novartis Animal Health US, Inc., Greensboro, NC

[b]Vision 7 with Spur, Intervet/Schering-Plough Animal Health, DeSoto, KS

[c]Ivermax® Pour-on for Cattle, RXV Products, Memphis, TN

[d]Safe-Guard Suspension 10%, Intervet/Schering-Plough Animal Health, DeSoto, KS

[e]Fusogard®, Novartis Animal Health US, Inc., Greensboro, NC

[f]Centurion™, Intervet/Schering-Plough Animal Health Corp., DeSoto, KS
[g]Elanco, Elanco Animal Health, Greenfield, IN
[h]SAS Version 9.1, SAS Institute, Cary, NC

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