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Long Term Feeding Effects of a Vaccine against of Endotoxemia (ENDOVAC-Beef) on Growth Performance and Carcass Characteristics of Growing-Finishing Calf-Fed Holstein Steers

Short Communication

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ABSTRACT

The objective was to evaluate the long-term effects of vaccination against endotoxemia on calf-fed Holstein steer growth performance, dietary energetics, and carcass characteristics. Fifty Holstein steer calves were used in a 322 d trial. Calves (134±5 kg) were randomly assigned to treatments within weight groups to 10 pens (5 steers per pen). Five pen groups received an endotoxemia vaccination on d 28 and 56 of the study (EV), and the remaining 5 pens did not receive vaccination. Calves were weighed (off-truck weight, no shrink applied) at start of the study, and on days 122 and 322 (shrunk 4% to account for gut fill). All steers were fed with a steam-flaked corn-based diet. Vaccination did not affect (P≥0.10) live weight, average daily gain, and dry matter intake during the experiment. Although vaccination increased (P=0.04) gain efficiency during the initial 112 d, differences in gain efficiency from d 112 to 322, and during the cumulative feeding period (1 to 322 d) was not appreciable (P≥0.14). Vaccination did not affect (P≥0.31) hot carcass weight, dressing percentage, or marbling score. However, vaccination increased (P<0.01) longissimus muscle area (86.5 *vs.* 76.8 cm^2) and retail yield (51.3 *vs.* 50.4); but, also tended to increase (P=0.07) carcass fat thickness. Morbidity and pink eye rate infection were low and not affected by treatment (P≥0.18). We conclude that whereas vaccinating Holstein calves with EV at days 28 and 56 from arrival did not have an overall effect on growth-performance, it increased (13%) longissimus area and retail carcass yield (1.8%).

KEY WORDS carcass, cattle, feed efficiency, gram-negative, vaccination.

INTRODUCTION

Gram-negative pathogens prevalent in feedlot operations (*E. coli*, *Salmonella*, *Pasteurella*, and *Mannheimia haemolytica*) contribute to morbidity and mortality associated with several diseases provoked by endotoxemia (Andersen, 2003). The use of rapidly degradable carbohydrates in feedlot diets increases the number of ruminal Gram-negative bacteria leading to increased ruminal endotoxin concentration (Nagaraja *et al.* 1978). Endotoxemia can increase morbidity and mortality of feedlot calves, negatively affecting profitability (Buda *et al.* 2023). Due to its nature, symptoms of endotoxemia may not be readily apparent, leading to decreases in cattle growth performance (Foley and Schlafer, 1994). Immunization against the more important Gram-negative bacteria prevalent in the feedlot is an ascertainable strategy for reducing the risk of endotoxemia. Through time, more specific vaccines have been developed. As opposed to whole-cell vaccines derived from live or killed microorganisms, containing myriads of antigenic components, acellular vaccines contain antigenic components that are well-defined and purified (Zhang *et al.* 2013). Vaccination against gram-negative bacteria has been shown to decrease the number of treated animals for secondary pneumonias associated with bovine respiratory disease (Melchner *et al.* 2021). Compared with non-vaccinated controls, sera antibodies produced in response to vaccination with specific toxoid (Sprouse *et al.* 1990) or with acellular vaccines (Roier *et al.* 2013), significantly attenuated clinical responses to *Escherichia coli*, *Pasteurella multocida*, *and Mannheimia haemolytica* endotoxins. Optimizing health status (lower morbidity and sick day rate) during the initial receiving and growing period can increase rate of weight gain resulting in both short and long-term positive effects on feedlot cattle growth performance (Galyean *et al.* 2022). There is no information regarding the long-term effects of vaccination with an acellular vaccine containing specific antigen components against endotoxemia on growth performance and carcass quality of feedlot cattle fed a high-energy diet for a prolonged finishing period (greater than 300 d). For this reason, the objective of this study was to evaluate the long-term influence of an acellular vaccine containing specific antigen components against endotoxemia (ENDOVAC-Beef®; ENDOVAC Animal Health, Columbia, MO) on calf-fed Holstein steer growth performance, dietary energetics, and carcass characteristics.

MATERIALS AND METHODS

Procedures for animal care and management were conducted under protocol (#20548) approved by the University of California, Animal Use and Care Advisory Committee.

Fifty Holstein steer calves (initial body weight=134 ±5 kg) were used to evaluate the long-term effects of a specific vaccine against of endotoxemia on growth performance, dietary energetics and carcass characteristics. The trial lasted 322-d feeding period. Calves originated from a commercial dairy calf ranch (Calf-Tech, Tulare, CA). Upon arrival at the University of California Desert Research and Extension Center (Holtville, CA), calves were vaccinated against Infectious Bovine Rhinotracheitis, Bovine Viral Diarrhea Virus, Parainfluenza-3, Respiratory syncytial virus, and *M. haemolytica* toxoid (Bovi-shield® Gold One Shot, Zoetis Animal Health, New York, NY), clostridials (Ultrabac® 7, Zoetis Animal Health, New York, NY), treated against internal and external parasites (Dectomax, Zoetis Animal Health, New York, NY), injected with 1,500 IU vitamin E (as d-alpha-tocopherol) 500,000 IU vitamin A (as retinyl-palmitate) and 50000 I.U. vitamin D3 (Vital E-AD, Stuart Products, Bedford, TX), and with 300 mg of the antibiotic tulathromycin (Draxxin, Zoetis Animal Health, New York, NY). Calves were blocked by initial shrunk off-truck body weight (SBW) and randomly assigned within weight groupings to 10 pens (five steers per pen, 5 pens per treatment). The five pen groups received an acellular vaccine which contain antigen components that are well-defined and purified against *Escherichia coli*, *Pasteurella multocida*, and *Mannheimia haemolytica* endotoxins (EV; ENDOVAC-Beef, Animal Health, Columbia, MO). Vaccinated calves received their first vaccination on d 28 from arrival and a booster vaccination on d 56. Calves were allowed *ad libitum* access to feed and water were allocated in pens (62 m^2 surface) with 25 m^2 overhead shade, automatic waterers and 2.4 m fence-line feed bunks. All calves received the same steam-flaked corn-based growing-finishing diet during the experiment (Table 1).

Table 1 Growing-finishing diet offered to Holstein calves

Ingredient composition, % Dry matter	%
Sudangrass hay	8.00
Alfalfa hay	4.00
Tallow	2.50
Molasses, cane	4.00
Distillers grains	10.00
Steam flaked corn	68.12
Urea	1.15
Limestone	1.68
Dicalcium phosphate	0.10
Magnesium oxide	0.15
Trace mineral salt[1]	0.30
Nutrient composition[2]	
Dry matter, %	87.9
NE_m, Mcal/kg	2.21
NE_g, Mcal/kg	1.53
Crude protein, %	14.3
Rumen degradable protein, %	62.7
Rumen undegradable protein, %	37.3
Ether extract, %	6.70
Ash, %	5.76
Nonstructural CHO, %	58.0
NDF, %	17.7
Calcium, %	0.80
Phosphorus, %	0.35
Potassium, %	0.77
Magnesium, %	0.28
Sulfur, %	0.19

[1] Trace mineral salt contained: $CoSO_4$: 0.068%; $CuSO_4$: 1.04%; $FeSO_4$: 3.57%; ZnO: 0.75%; $MnSO_4$: 1.07%; KI: 0.052% and NaCl: 93.4%.
[2] Calculated based on tabular values for individual feed ingredients (NASEM, 2016).
NE_m: net energy for maintenance; NE_g: net energy for gain and NDF: neutral detergent fiber.

On d 112 and d 224, all steers were reinjected subcutaneously with 500,000 IU vitamin A (Vital E-A+D, Stuart Products, Bedford, TX) and implanted with Revalor-S (Intervet, Millsboro, DE). All calves were slaughtered on the same day. Hot carcass weights (HCW) and liver abscess incidence (based on size and number, scaled as 0, A−, A, and A+; Herrick *et al.* 2022), as well as liver scaring measures were obtained at the time of slaughter. After carcasses chilled for 24 h, the following measurements were obtained: Carcass color (Baublits *et al.* 2004; using scale from 1 to 8 where 1.0

is bleached red and 8.0 very dark red); longissimus muscle area (LMA, cm^2) by direct grid reading of the muscle at the 12^{th} rib; subcutaneous fat (cm) over the LM at the 12^{th} rib taken at a location 3/4 the lateral length from the chine bone end (adjusted by eye for unusual fat distribution); kidney, pelvic and heart fat (KPH) as a percentage of HCW; marbling score (USDA 1997; using 3.0 as minimum slight, 4.0 as minimum small, 5.0 as minimum modest, 6.0 as minimum moderate, etc.), and preliminary as well as estimated retail yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck as a percentage of HCW (Yield, %= 52.56-1.95×subcutaneous fat-1.06×KPH+0.106×LM area - 0.018×HCW; Murphey *et al.* 1960).

Average daily gain (ADG) was determined as the difference in initial SBW (off-truck weight) and weights registered on days 112 d and 322 (weight taken before morning feed and multiplied by 0.96 for convert to shrunk body weight) divided by period of test (112 and 322 days on test). Gain efficiency (G:F) was determined as the ADG divided by corresponding dry matter intake (DMI). For dietary net energy estimation, energy gain (EG, Mcal/d) was derived from measures of SBW (kg) and ADG (kg/d) according to the equation: $EG= (0.0557\ W^{0.75})\ ADG^{1.097}$ (NRC, 1984). Net energy content of the diet for maintenance and gain were calculated assuming constant maintenance energy (EM, Mcal/d) of $0.086W^{0.75}$ (NRC, 1988). The NE values of the diets for maintenance and gain were obtained by means of the quadratic formula (Zinn *et al.* 2008):

NE_m, Mcal/kg= $(-b-\sqrt{b^2-4ac}) / 2a$

Where:
$a= -0.877DMI$.
$b= 0.877EM + 0.41DMI + EG$.
$c= -0.41EM$.
$NE_g= 0.877NE_m - 0.41$.

The data were analyzed as a randomized complete block design experiment according to the following statistical model:

$$Y_{ij}= \mu + B_i + T_j + E_{ij}$$

Where:
μ: common experimental effect.
B_i: initial weight group effect.
T_j: dietary treatment effect.
E_{ij}: residual error (Statistix 10, Analytical Software, Tallahassee, FL).

Animal health data were analyzed using chi-square analysis. Pens served as the experimental unit for all analyses. Least squares means were compared using Tukey test. Significant differences among treatments were declared at P ≤ 0.05 and tendencies were declared at P-value between > 0.05 ≤ 0.10.

RESULTS AND DISCUSSION

Only one steer from control group was culled in the first week of the experiment. Treatments effects on growth performance and estimated dietary NE are shown in Table 2.

Table 2 Vaccine effects on growth-performance of calf-fed Holstein steers

Item	ENDOVAC-Beef[1] -	ENDOVAC-Beef[1] +	SEM	P-value
Days on test	322	322		
Pen replicated	5	5		
Live weight, kg[2]				
Initial	134.3	134.6	0.14	0.28
112 d	284.0	290.0	2.0	0.10
Final	594.4	605.7	10.0	0.47
ADG, kg				
1-112 d	1.34	1.39	0.02	0.13
112-322 d	1.48	1.50	0.04	0.66
1-322 d	1.43	1.46	0.03	0.48
DMI, kg/d				
1-112 d	6.01	6.07	0.08	0.62
112-322 d	8.95	8.94	0.19	0.96
1-322 d	7.93	7.94	0.15	0.96
ADG/DMI, kg/kg				
1-112 d	0.222	0.229	0.001	0.04
112-322 d	0.165	0.168	0.002	0.27
1-322 d	0.180	0.184	0.002	0.14
Dietary net energy, Mcal/kg[3]				
Maintenance	2.17	2.21	0.02	0.15
Gain	1.49	1.53	0.02	0.15
Observed/ expected dietary net energy[3]				
Maintenance	0.98	1.00	0.01	0.15
Gain	0.97	1.00	0.01	0.15

[1] Groups received the ENDOVAC-Beef (Animal Health, Columbia, MO) vaccination on d 28 and d 56.
[2] Initial weight is the off-truck arrival weight. All other weights are full live weights reduced 4% to account for digestive tract fill.
[3] Dietary energy estimation and observed-to-expected diet NE were considered entire period
ADG: average daily gain and DMI: dry matter intake.
SEM: standard error of the means.

Vaccinated steers tended to have greater live weight on day 112 (P=0.10), though intermediate 112 to 322 weight and final live weights were not different (P=0.47). Vaccination did not affect (P≥0.13) overall dry matter intake or ADG. However, during the initial 112-d period, gain efficiency was greater for steers that received the endotoxemia vaccination (P=0.04).

Gain efficiency and dietary net energy were not affected as a result of an endotoxemia vaccination during the subsequent 210 d on feed, or overall (P≥0.14).

In a previous study, sera antibodies produced as a result of ENDOVAC-Beef vaccination significantly reduced clinical responses to *Escherichia coli*, *Pasteurella multocida*, and *Mannheimia haemolytica* endotoxins (Sprouse *et. al.* 1990). By optimizing health status (reducing morbidity, detected or otherwise), enhancements in both short- and long-term growth performance may occur. In the present study, beneficial effects of vaccination on gain efficiency during the initial period were not apparent during the final 210-d period or during the cumulative feeding period. The magnitude of the positive effects of vaccination against gram-negative bacteria on growth performance are mediated by the prevalence of the risk factors (i.e. errors in feed formulation, in feed bunk management, late detection of sick animals, etc.). Under optimal feeding management conditions, differences (on long-term growth performance indicators) between vaccinated vs unvaccinated may not be expected. In this sense, overall (322 d) ADG in the present study was 1.45 kg/d. This rate of gain is consistent with the ADG of 1.44 kg/d observed in previous growing-finishing studies conducted at this center involving Holstein steers consuming similar diets (1.37 kg/d, Carvalho *et al.* 2021; 1.44 kg/d, Carvalho *et al.* 2022; 1.53 kg/d, Latack *et al.* 2022; 1.42 kg/d, Carvalho *et al.* 2023). Likewise, overall estimated dietary net energy based on growth performance was in close agreement (99%) with expected based on diet formulation.

Treatment effects on carcass characteristics, liver abscess incidence, liver scars measure and morbidity are shown in Table 3.

Table 3 Vaccine effects on carcass characteristics, liver abscess and morbidity

Item	ENDOVAC-Beef [1] -	ENDOVAC-Beef [1] +	SEM	P-value
Hot carcass weight, kg	369.1	376.1	6.22	0.47
Dressing percentage	61.9	62.2	0.19	0.52
Kidney-pelvic-heart fat, %	3.28	3.23	0.06	0.57
Fat thickness, cm	0.78	0.91	0.04	0.07
Longissimus muscle area, cm^2	76.80	86.50	1.60	< 0.01
Marbling score [2]	4.57	4.34	0.15	0.31
Retail yield [3]	50.4	51.3	0.13	< 0.01
Yield Grade	3.20	2.90	0.06	0.01
Color[4]	5.56	5.76	0.10	0.23
Abscessed liver, %	4.00	8.00	5.30	0.62
Liver abscess scars no abscess	0.16	0.37	0.06	0.08
Pinkeye, %[5]	0.00	4.00	6.30	0.37
Morbidity, %	4.00	12.00	3.50	0.18

[1] Groups received the ENDOVAC-Beef (Animal Health, Columbia, MO) vaccination on d 28 and d 56.
[2] Using code of: 3.0 as minimum slight, 4.0 as minimum small, 5.0 as minimum modest, 6.0 as minimum moderate, etc.).
[3] Estimated retail yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck as a percentage of HCW (Yield, %= 52.56 - 1.95 × subcutaneous fat - 1.06 × KPH + 0.106 × LM area - 0.018 × HCW; Murphey *et al.* 1960).
[4] Using scale from 1 to 8 where 1.0 is bleached red and 8.0 very dark red (Baublits *et al.* 2004)
[5] Only 1 of the 50 calves on this study was treated for pinkeye.
SEM: standard error of the means.

There was no treatment effect on carcass weight, dressing percentage, KPH fat, marbling score, or color (P>0.10). Steers vaccinated with the EV tended to have greater backfat (P=0.07). However, longissimus area (P<0.01) and retail yield (P<0.01) were greater for steers that received the EV vaccination. The 1.8% greater calculated retail yield for steers that received the EV vaccine is largely due to the 12.6% greater longissimus area (Murphey *et al.* 1960). The basis for the increased longissimus area with ENDOVAC-Beef vaccination is uncertain. However, in a feedlot study involving crossbred steers, vaccination with ENDOVAC-Beef likewise increased longissimus area (4.3%, P<0.01) above that of non-vaccinated steers (PhD David P. Hutcheson, personal communication).

Morbidity (8%) and pink eye rate infection (2%) were low and not affected by treatment (P≥0.18). Steers that received the ENDOVAC-Beef vaccination tended to have greater incidence of liver abscess scars (P=0.08). The practical significance of liver scar measures is uncertain. Factors including infection, inflammation, and fatty liver may lead to scarring. Liver scars have also been attributed to abscess regression (Nagaraja and Lechtenberg, 2007). Nevertheless, the practical relationship between presentation of liver scars and feedlot cattle performance is not apparent. Latack *et al.* (2021) observed that on an individual animal basis, ADG of steers that presented liver scars at harvest was not different from that of steers with no liver scarring (1.48 *vs.* 1.47 kg, respectively).

CONCLUSION

Vaccinating calf-fed Holstein steers with an endotoxemia vaccination increased gain efficiency during the initial 112-d period, but did not have an overall effect on growth-performance (322-d). However, vaccination increased (13%) longissimus muscle area and carcass retail yield (1.8%). Further research is need to understand the basis for the marked effects of vaccination on longissimus area. Although there is no statistical difference between those who were vaccinated and those who were not, the low fat content and the approximately 7 kg excess of longissimus muscles (precious muscles) on the carcass could increase the business income.

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