Effect of alpha-tocopherol acetate and ascorbic acid on performance, carcass traits, and incidence and severity of liver abscesses in feedlot cattle

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ABSTRACT: Liver abscesses (LA) in cattle negatively affect feedlot performance by decreasing ADG, feed intake, and G:F ratio. Abscessed livers are condemned and abdominal adhesions associated with LA can result in extensive carcass trimming during harvest, further compounding adverse economic impact. Given regulatory changes pertaining to the use of in-feed antibiotics in cattle production, there is growing interest in alternatives to antibiotics for LA control. The objective of this study was to evaluate the use of antioxidants, crystalline ascorbate (AOX), and alpha-tocopherol acetate, for mitigation of LA in feedlot cattle. Yearling crossbred heifers ($n = 392$; initial BW 481 ± 9.4 kg) were blocked by previous treatment and allocated randomly to 24 dirt-surfaced feedlot pens ($10 \text{ m} \times 35 \text{ m}$) with 14 heifers/pen. Heifers were weighed, implanted with Component TE-200 implants, and placed into feeding pens. Finishing diets consisted of 60% steam-flaked corn,

30% wet corn gluten feed, 8% alfalfa, and 2% supplement (DM basis) that provided 300 mg/d monensin, and either 200 IU/d alpha-tocopherol acetate (CTL) or 2,000 IU/d alpha-tocopherol acetate plus 500 mg/d crystalline AOX. Heifers were fed once daily ad libitum for 94 d, then weighed and transported 450 km to a commercial abattoir for harvest. Hot carcass weight and incidence/severity of LA were determined the day of harvest, and carcass traits were evaluated following 36 h of refrigeration. Compared to CTL, feeding AOX tended to decrease DMI (10.66 vs. 10.31 kg/d; $P = 0.08$) and improve G:F (0.1204 vs. 0.1254; $P = 0.12$), but did not impact ADG, incidence of LA (25.6 vs. 23.5% for CTL and AOX, respectively), HCW (828.4 vs. 830.5 kg for CTL and AOX, respectively), or other carcass traits ($P > 0.20$). In conclusion, feeding antioxidants are not a viable alternative to decrease incidence of LA in finishing cattle.

Key words: antioxidant, feedlot, liver abscess

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INTRODUCTION

Liver abscesses (LA) are a significant source of economic loss in feedlot cattle. These losses arise due to a decline in feedlot performance and more notably due to a decline in carcass value. McKeith *et al.* (2012) reported that 13.7% of livers were condemned due to major and minor abscesses. Hot carcass weight decreases due to trim loss associated with abscessed livers, as a portion of the diaphragm adheres to livers that have severe

abscesses (Brown and Lawrence, 2010; Rezac *et al.*, 2014). Cattle with severe LA had 0.17 kg/d lower ADG (Rezac *et al.*, 2014), poorer G:F (Brink *et al.*, 1990), and decreased DMI (Brink *et al.*, 1990) when compared to healthy animals.

Tylosin phosphate is a macrolide antibiotic that is used for prevention of LA (Tan *et al.*, 1994; Nagaraja and Lechtenberg, 2007; Reinhardt and Hubbert, 2015) and is effective in decreasing the occurrence of LA in cattle (Tan *et al.*, 1994; Vogel and Laudert, 1994; Meyer *et al.*, 2013). In 2013, the FDA issued Guidance For Industry (GFI) #213 which encourages reduced use of medically important antibiotics in animal feeding operations (FDA GFI 213, 2013).

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Singh *et al.* (2012) observed that α -tocopherol protected intestinal tissue of irradiated mice. Research on the effects of α -tocopherol acetate in ruminants showed an increase in humoral immune response (Peplowski *et al.*, 1981; Droke and Loerch, 1989; Cusack *et al.*, 2005) and cattle receiving supplemental α -tocopherol acetate had less ruminal lesions in their ventral sac (Arnold *et al.*, 1992). Tappel (1968) and Packer *et al.* (1979) showed a synergistic relationship between ascorbate (AOX) and α -tocopherol acetate. The objective of this study was to determine the effect of antioxidants on feedlot performance, carcass characteristics, and incidence and severity of LA in feedlot heifers fed a finishing ration that contained no tylosin.

MATERIALS AND METHODS

Live animal procedures were approved by and conducted within regulations set by the Kansas State University Institutional Animal Care and Use Committee.

Experimental Design

The study was designed as a randomized complete block design that consisted of two treatments. Three hundred and ninety-two heifers were selected from a group of 448 heifers that were already housed at the Kansas State University Beef Cattle Research Center (Manhattan, KS) and blocked by study treatments they received during a growing study completed prior to the current study. The objective of the growing study was to determine how different concentrations of ruminal bypass lysine affected growth performance on a roughage-based diet. After the heifers were blocked, they were randomly assigned to one of two treatments. Treatments consisted of a control in which the diet contained 22 IU/kg supplemental α -tocopherol acetate (Control), and an antioxidant treatment in which the diet contained α -tocopherol acetate and crystalline AOX supplemented at a rate of 220 IU/kg and 550 mg/kg, respectively (Antioxidant).

Heifers were housed in 28 soil-surfaced pens that contained 14 heifers per pen. Pens were designed to allow for approximately 20.44 m² space per heifer. Each pen contained automatic waterers that were located between adjacent pens and were approximately 6 m from feed bunks. Feed bunks provided approximately 76 cm of bunk space per heifer.

Cattle Processing

At the start of the growing study, heifers received individual identification in the form of an ear tag, a vaccine that contained clostridial antigens

(Ultrabac 7/Somnubac, Zoetis Animal Health, Florham Park, NJ), a five-way respiratory vaccine (Bovishield Gold 5, Zoetis Animal Health), and an anti-parasitic pour-on treatment (Standguard, Elanco Animal Health, Greenfield, IN). At the start of the finishing study, individual BW was obtained, heifers were implanted with Component TE-200 with Tylan (Elanco Animal Health) and were sorted into their respective experimental pens.

Average BW was obtained at 28-d intervals and at the end of the 94-d feeding period. Average BW was determined by dividing pen weight by the number of heifers in a pen. A large platform scale (Central City Scale, Central City, NE), set on four electronic load cells, was used to determine pen weights. Load cells were calibrated and verified with certified 1,021 kg weights before every use. Average daily gain and G:F were determined from average BW. Average daily gain was determined by subtracting previous pen weight from current pen weight and dividing by days on feed. Feed efficiency was determined by dividing ADG by average DMI.

Diet Preparation

Heifers were adapted to a high concentrate finishing ration using four step-up rations fed over 21 d. Ingredient and nutritional composition of the finishing ration are presented in Table 1. Treatment diets contained no tylosin phosphate.

Heifers were fed once daily starting at approximately 0800 h using a truck-mounted feed mixer. Control diets were fed first followed by the antioxidant diets and after each diet was fed the feed mixer was cleaned. Feed was visually inspected daily and adjustments were made, based on how much feed was left over in the feed bunks from the previous feeding, to provide ad libitum intake. Unconsumed feed was removed from the pens on days when pens were weighed and on days when there were excessive precipitation events to determine DMI and G:F. Dry matter of the unconsumed feed was determined by drying the sample in a 55 °C oven for 48 h. Dry matter intake was determined as follows:

$$\text{DMI} = \frac{\left[(\text{total feed delivered} \times \text{DM } \%) \right] - \left[(\text{unconsumed feed} \times \text{DM } \%) \right]}{\text{number of heifers in pen}}$$

Harvest

After 94 d, final pen weights were obtained to determine average final BW and this value was then

Table 1. Composition of diets to assess effect of supplemental α -tocopherol acetate and crystalline ascorbate on liver abscess incidence and severity of feedlot heifers

Item	
Ingredient, % DM	
Steam-flaked corn	60.10
Sweetbran ¹	30.00
Corn silage	8.00
Limestone	1.49
Salt	0.30
Vitamin/mineral premix ²	0.11
Nutrient composition (DM basis)	
CP, %	13.40
NE _m , MJ/kg	2.11
NE _g , MJ/kg	1.46
NDF, %	19.58
Ca, %	0.69
P, %	0.48
Salt, %	0.30

¹Wet corn gluten feed, Cargill Starches & Sweeteners North America, Minneapolis MN.

²Formulated to provide (on a total diet DM basis) 0.15 mg/kg cobalt, 10 mg/kg copper, 0.50 mg/kg iodine, 20 mg/kg manganese, 0.10 mg/kg selenium, 30 mg/kg zinc, 2200 IU/kg vitamin A, 22 IU/kg α -tocopherol acetate, and 33 mg/kg monensin (Rumensin, Elanco Animal Health). α -Tocopherol acetate was added to the supplement to provide 200 IU/kg α -tocopherol acetate and crystalline ascorbic acid was added to the supplement at a rate of 550 mg/kg for the antioxidant treatment.

multiplied by 0.96 to adjust for 4% shrink loss during shipping. Heifers were transported approximately 450 km to a commercial abattoir. Hot carcass weight and liver abscess scores were obtained on the day of harvest. Liver abscesses were scored according to the system set out by [Brown et al. \(1975\)](#) where: 0 = no abscess, A- = one or two small abscesses (mild), A = two to four well-organized abscesses usually not larger than 2.5 cm in diameter (moderate), or A+ = 1 or more large abscess with inflammation surrounding the abscess and is usually characterized by a portion of the diaphragm being adhered to the liver (severe). Liver abscesses were assessed by a trained individual from Kansas State University observing USDA officials as they assessed the liver. United States Department of Agriculture quality and yield grades, incidence of dark cutters, LM area, 12th rib subcutaneous fat thickness, and marbling score were obtained using camera imaging software (VBG 2000; E+V Technology GmbH & Co. KG, Oranienburg, Germany) after a 36-h refrigeration period.

Statistical Analysis

Feedlot performance (initial and final BW, ADG, DMI, and G:F) and noncategorical carcass

data (HCW, dressing percentage, LM area, 12th rib subcutaneous fat thickness, marbling score, and overall yield grade) were analyzed using the MIXED procedure of SAS version 9.4. The GLIMMIX procedure was used to analyze categorical carcass data (liver abscess incidence and severity, USDA quality, and yield grades). Models contained pen as experimental unit, treatment as fixed effect and block as random effect. Differences in LS means were compared using the PDIF function of SAS. Treatment effects were declared significant at $P < 0.05$ and $0.05 > P \geq 0.01$ was declared as a tendency.

An adjustment for unequal variances using the Tukey method was made when we tested the effect that liver abscess severity had on HCW gain.

RESULTS AND DISCUSSION

One heifer from the control group was removed from study due to a physical injury. Three heifers were removed from the antioxidant treatment. Reasons for removals were not related to treatments.

No interaction effects were detected between previous treatment received in the growing study and finishing study treatment.

Feedlot Performance

Feedlot performance is presented in [Table 2](#). No differences were detected between treatments for any feedlot performance parameters ($P > 0.05$). There was a tendency for decreased DMI when the antioxidants were included in the ration ($P = 0.08$), which lead to a tendency for improved G:F ($P = 0.07$). Similar to our results, [Burken et al. \(2012\)](#) observed a tendency for improved G:F that was driven by a tendency for a decrease in DMI when finishing diets containing supplemental vitamin E were compared to a diet containing no vitamin E. This observation can be explained by the impacts that α -tocopherol acetate and AOX have on ruminal fermentation characteristics. α -Tocopherol acetate has been shown to increase ruminal bacteria activity and therefore total VFA production ([Hidiroglou and Lessard, 1976](#); [Hino et al., 1993](#); [Naziroglu et al., 2002](#)). [Tagliapietra et al. \(2013\)](#) observed an increase in microbial activity when AOX was supplemented to a corn-based diet in vitro. In contrast, [Pogge and Hansen \(2013\)](#) found no differences in feedlot performance when they compared high-grain finishing rations that contained supplemental vitamin C with those that did not contain supplemental vitamin C. [Arnold et al. \(1992\)](#), [Yang et al. \(2002\)](#), and [Burken et al.](#)

Table 2. Effect of supplemental α -tocopherol acetate and ascorbate as an alternative treatment for liver abscess control on feedlot performance of heifers

Item	Control ¹	Antioxidant ²	SEM	P value
Initial BW, kg	481.4	482.1	9.45	0.76
Final shrunk BW, kg	601.4	602.9	7.68	0.70
ADG, kg/d	1.28	1.31	0.036	0.70
DMI, kg/d	10.72	10.36	0.191	0.08
G:F	0.1201	0.1251	0.0023	0.07

¹Diet contained 22 IU/kg α -tocopherol acetate.

²Diet contained 200 IU/kg α -tocopherol acetate and 550 mg/kg crystalline ascorbate.

(2012) also observed similar results to Pogge and Hansen (2013) when supplemental vitamin E was added to high-grain finishing rations. Cusack *et al.* (2009) did a meta-analysis to determine the effect of vitamin E supplementation on feedlot performance and found no effect of vitamin E supplementation on ADG, DMI, or G:F

Carcass Characteristics

Carcass characteristics are presented in Table 3. No differences were observed between control and antioxidant treatment for HCW, dressing percentage, LM area, 12th rib subcutaneous fat thickness, marbling score, or USDA quality grades. These results are consistent with observations by Arnold *et al.* (1992), Burken *et al.* (2012), and Pogge and Hansen (2013) who observed no differences in carcass traits when α -tocopherol acetate or AOX was supplemented to the diet. We hypothesized that this may be due to the requirements for vitamin E and C already being met by the diets the heifers were receiving.

More yield grade 1 carcasses were observed for heifers that received the control diet compared to those supplemented with α -tocopherol acetate and AOX ($P = 0.007$), whereas heifers that received supplemental α -tocopherol acetate and AOX had more yield grade 3 carcasses. Rivera *et al.* (2002) and Burken *et al.* (2012) found that with high α -tocopherol acetate supplementation rates, yield grades of carcasses increased compared to treatments where no α -tocopherol acetate was supplemented. One hypothesis for the increase in yield grade 3 carcasses we observed is that a slight increase in 12th rib fat thickness and HCW was also seen carcasses where heifers received supplemental α -tocopherol acetate, which may be attributable to the tendency for improved feedlot performance observed when heifers were supplemented with α -tocopherol acetate and AOX.

Table 3. Effect of supplemental α -tocopherol acetate and ascorbate as an alternative treatment for liver abscess control on carcass characteristics of feedlot heifers

Item	Control ¹	Antioxidant ²	SEM	P value
HCW, kg	377.9	379.3	4.83	0.50
Dressed yield, %	62.82	62.91	0.001	0.64
12 th Rib fat thickness, cm	1.49	1.54	0.012	0.11
LM area, cm ²	94.1	94.5	0.79	0.59
Marbling score ³	507	509	8	0.87
USDA prime, %	9.6	7.4	2.17	0.30
USDA choice, %	68.4	71.8	3.72	0.38
USDA select, %	16.4	13.2	3.54	0.13
Sub-select ⁴ , %	5.6	7.6	2.56	0.20
USDA yield grade	2.5	2.6	0.11	0.85
Yield grade 1, %	12.3	4.2	2.81	0.01
Yield grade 2, %	38.0	40.5	5.01	0.63
Yield grade 3, %	37.4	46.3	4.97	0.03
Yield grade 4, %	11.3	9.0	2.93	0.12
Yield grade 5, %	1.0	0.0	3.08	0.70

¹Diet contained 22 IU/kg α -tocopherol acetate.

²Diet contained 200 IU/kg α -tocopherol acetate and 550 mg/kg crystalline ascorbate.

³Marbling score determined by computer imaging system (VBG 2000, E+V Technology GmbH & Co. KG, Oranienburg, Germany): 300 to 399 = slight; 400 to 499 = small; 500 to 599 = modest.

⁴Consists of carcasses grading USDA Standard and USDA Commercial.

Response of HCW gain to different severities of LA is presented in Fig. 1. No interaction between treatment and liver abscess severity on HCW gain was detected ($P = 0.27$), and no effect of liver abscess on HCW was detected for any of the treatments ($P > 0.6$). Our data were restricted to the number of livers that had a particular severity score per treatment and therefore, we have high SE within the treatment groups and severity groups. Brink *et al.* (1990) found that animals that had mild LA had an increase in HCW gain compared to animals that had no LA.

Liver Abscess Incidence and Severity

Liver abscess incidence and severity is presented in Table 4. No differences in liver abscess incidence or severity were detected between the control and antioxidant treatment. Our incidence of liver abscess observed for both treatments was similar to those observed by Vogel and Laudert (1994), Meyer *et al.* (2009), and Maxwell *et al.* (2014) when tylosin was removed from the diet, indicating that increased amount of α -tocopherol acetate and crystalline AOX likely has no effect on incidence of abscesses. Concurrently, Arnold *et al.* (1992) reported no difference in liver abscess severity when

Figure 1. Effect of liver abscess severity on HCW gain. Control treatment (black) contained 22 IU/kg α -tocopherol acetate. Antioxidant (gray) treatment contained 200 IU/kg α -tocopherol acetate and 550 mg/kg crystalline ascorbate for 94 d of finishing. Liver abscesses scored as described by Brown *et al.* (1975). ¹HCW gain = HCW – (initial BW $\times$ 0.56). No treatment $\times$ liver abscess effect, $P = 0.27$. No effect of treatment or liver abscess severity, $P > 0.6$.

Table 4. Effect of supplemental α -tocopherol acetate and ascorbate as an alternative treatment for liver abscess control on liver abscess incidence and severity of feedlot heifers

Liver abscess, ¹ %	Control ²	Antioxidant ³	SEM	P value
Total	25.7	23.6	4.37	0.63
Mild	18.0	19.0	3.97	0.82
Moderate	5.7	3.2	2.10	0.23
Severe	1.6	1.1	1.16	0.67

¹Brown *et al.* (1975).

²Diet contained 22 IU/kg α -tocopherol acetate.

³Diet contained 200 IU/kg α -tocopherol acetate and 550 mg/kg crystalline ascorbate.

steers, weighing approximately 227 kg, received finishing rations that were supplemented with 110 IU/kg α -tocopherol acetate and contained no tylosin. They also observed fewer ruminal lesions in the ventral sack of the rumen, indicating that even though α -tocopherol acetate decreased the occurrence of lesions in the ruminal wall, the incidence of liver abscess was still high.

IMPLICATIONS

Supplementing α -tocopherol acetate and AOX at high concentrations to finishing rations does not reduce incidence and severity of LA when compared to a control diet. These antioxidants tend to improve feed efficiency.

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