

Effects of liver abscess severity and quality grade on meat tenderness and sensory attributes in commercially finished beef cattle fed without tylosin phosphate¹

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ABSTRACT: Strip loin steaks ($n = 119$) were used to evaluate the association between liver abscess severity and USDA quality grade and meat tenderness and sensory attributes of steaks from finished feedlot cattle. Steaks were used in a 3×2 factorial treatment structure using a completely randomized design and were collected at a commercial abattoir located in northwest Texas. All cattle were sourced from a single feedlot and fed a common diet that did not include tylosin phosphate. Treatments were USDA quality grades of Select (SEL) and Low Choice (LC) and liver abscess scores of normal (NORM; healthy liver, no abscesses), mild (M; 1 abscess less than 2 cm in diameter to 4 abscesses less than 4 cm in diameter), and severe (SV; 1 abscess greater than 4 cm in diameter or greater than 4 small abscesses). All steak samples were collected on the same day, approximately 36-h post-mortem and were cut from the left side of the carcass at the 13th rib by a trained abattoir employee. Steaks were vacuum-packaged, and aged at $3 \pm 1^\circ\text{C}$ for 14-d post-mortem. Warner-Bratzler Shear Force (WBSF) and

Slice Shear Force (SSF) analyses were conducted and cook-loss percentage was measured. A trained sensory panel analyzed samples for juiciness, tenderness, and flavor attributes. There were no differences among liver abscess scores for WBSF or SSF ($P > 0.52$). Warner-Bratzler Shear Force was lower for LC-SV than SEL-SV ($P = 0.04$). Sensory attributes of initial and sustained juiciness, and overall tenderness were all greater for LC than for SEL steaks ($P < 0.04$) and connective tissue amount was less for LC steaks when compared to SEL ($P = 0.03$). Liver abscess score had no effect on any sensory attributes ($P > 0.70$); however, there was an interaction between quality grade and liver score for myofibrillar tenderness ($P = 0.03$). Within LC steaks, liver abscess score had no effect on myofibrillar tenderness ($P > 0.05$), however, in SEL steaks, M steaks were more tender than SV steaks ($P < 0.03$). These results indicate that within quality grades, meat tenderness or sensory attributes were not influenced by liver abscess score but that mild liver abscesses may affect the myofibrillar tenderness of SEL steaks.

Key words: cattle, feedlot, liver abscesses, meat tenderness, palatability, quality grade

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INTRODUCTION

Liver abscesses are a significant problem in the United States' cattle feeding industry, costing the industry an estimated \$15.9 million annually in liver condemnation, trim losses, and reduced carcass weights and quality grades (Brown and Lawrence, 2010; Hicks,

2011). The 2011 National Beef Quality Audit reported the average prevalence of liver abscesses in cattle surveyed was 13.7% (McKeith et al., 2012) with incidence rates ranging from 10% to 20% in recent literature (Amachawadi and Nagaraja, 2016). Previous reviews have reported liver abscess incidence may be influenced by a number of factors including: breed, gender, diet, d on feed, cattle type, season, and geographical location (Nagaraja et al., 1996; Reinhardt and Hubbert, 2015).

Liver abscesses occur subsequently to rumen insults caused by acidosis or rumenitis, often referred to as the "rumenitis-liver abscess complex" (Jensen et al., 1954). Cattle fed readily-fermentable concentrate-based diets

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often have lower rumen pH levels that have the potential to cause damage to ruminal epithelium tissue (Haskins et al., 1969). It has been proposed that pathogens associated with liver abscess formation enter the blood stream through perforated rumen epithelium and are transported to the liver through the portal vein (Nagaraja and Chengappa, 1998).

Brown and Lawrence (2010) showed a reduction in HCW, dressing percentage, yield grade, LM area, and marbling scores for carcasses with liver scores of A+ when compared to those with normal livers. Brown and Lawrence (2010) also reported decreased marbling scores for severe liver abscesses with adhesions when compared to their counterparts with normal livers. Although the effect on carcass characteristics has been researched, no previous work has evaluated effect of liver abscess status on meat tenderness and sensory attributes. Therefore the objective of this study was to determine the effect of liver abscess severity on meat tenderness and sensory attributes of beef from 2 USDA quality grades.

MATERIALS AND METHODS

Institutional Animal Care and Use Committee approval was not required for this study because no live animals were handled. The protocols for the use of human subjects for this study were reviewed and approved by the Kansas State University Institutional Review Board (IRB #7440).

Carcasses

For this study, *Bos Taurus* cattle originated from the same commercial feedlot and were fed common diets that did not contain tylosin phosphate. All carcasses utilized in this study were from cattle that were slaughtered on a single day at a commercial abattoir in northwest Texas and carcasses were selected after lungs and livers were scored. Only carcasses with healthy, normal lung scores were utilized to avoid any potential effects on tenderness or sensory attributes caused by respiratory disease.

Liver Scores

Liver scores were evaluated and recorded by trained university observers at harvest using the scoring system previously defined by Rezac et al. (2014). Livers were scored as 0 (no abscesses); A- (1 to 2 abscesses less than 2 cm in diameter); A (2 to 4 abscesses between 2 and 4 cm in diameter); A+ (1 abscess greater than 4 cm in diameter or greater than 4 small abscesses); A+/AD (A+ criteria with adhesions to the body cavity; Rezac et al., 2014). For this study, 0 represented the normal (NORM) liver population, A- and, A represented the mild (M) liver abscess population, and A+, and A+ with adhe-

sions represented the severe (SV) liver abscess population. At the time of liver scoring, carcasses were given a sequence number that was then correlated back to the plant identification number.

Steak Collection

Quality grades of USDA Low Choice (LC) and Select (SEL) and liver abscess scores of NORM, M, and SV were used for this study. Carcasses were chilled for approximately 36-h post-mortem before grading. As carcasses passed across the grading stand, plant identification numbers, visible on carcass tags, in addition to the USDA quality grade, were used to identify carcasses in each of the categories. Colored tags were placed into the carcasses of interest and they were railed off for steaks to be collected. Strip loin steaks were cut approximately 6.35 cm thick from the left side of the carcass at the 13th rib by a trained abattoir employee the same day they were graded. Steaks from a total of 119 carcasses were collected and consisted of the following: 22 LC-NORM, 20 LC-M, 20 LC-SV, 21 SEL-NORM, 20 SEL-M, and 16 SEL-SV (Table 1). Steaks were put into labeled Ziploc freezer bags and put on ice to be transported back to Manhattan, KS, where steaks were vacuum-packaged and aged at $3 \pm 1^\circ\text{C}$ for 14 d post mortem. Steaks were stored for 48-h at -20°C then faced and cut into two 2.54 cm steaks using a band saw. The more anterior steak was used for sensory panel and the more posterior steak was used for instrumental tenderness measures.

Shear Force Measurements

Lab assays were conducted at the Kansas State University Meat Lab (Manhattan, Kansas). Warner-Bratzler Shear Force (WBSF) and Slice Shear Force (SSF) were conducted according to the American Meat Science Association Research Guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat (American Meat Science Association, 2015). Steaks were randomized using a random number generator and thawed for 24 h at 3°C . Steaks were weighed before and after cooking to calculate cook-loss. Before cooking, a 30 gauge copper/constantan thermocouple was inserted into the geometric center of each steak. Steaks were cooked on clamshell grills (Cuisinart, East Windsor, NJ) set to 176.7°C that had been sprayed with nonstick cooking spray. Internal temperatures were monitored with a Doric Minitrend 205 monitor (VAS Engineering, San Francisco, CA). Steaks were removed from the grill when an internal temperature of 65.6°C was reached for a target endpoint temperature of 70°C . Once maximum rise in temperature was reached, thermocouples were removed and steaks cut for SSF using

Table 1. Least squares means and SEM for effects of liver abscess score on sensory analysis panel items for USDA Low choice and Select beef strip loin steaks

Item	Treatments									
	Quality grade				Liver abscess score ¹					QG × LA
	Select, n = 57	Low choice, n = 62	SEM	P-value	None, n = 43	Mild, n = 40	Severe, n = 36	SEM	P-value	
Initial Juiciness ²	55.11 ^a	59.06 ^b	1.42	0.01	57.83	56.50	56.93	1.61	0.71	0.37
Sustained Juiciness	46.20 ^a	49.58 ^b	1.26	0.01	48.18	47.62	47.86	1.45	0.94	0.66
Myofibrillar Tenderness	57.51 ^a	62.41 ^b	1.53	0.02	59.84	60.84	59.21	1.90	0.81	0.03
Connective Tissue Amount	17.05 ^a	13.89 ^b	1.38	0.03	15.24	14.84	16.33	1.60	0.70	0.06
Overall Tenderness	53.96 ^a	58.81 ^b	1.65	0.03	56.62	57.20	55.33	2.05	0.79	0.08
Beef Flavor Identity	47.05	48.39	0.87	0.27	48.39	47.67	47.10	1.10	0.68	0.10
Off Flavor	0.91	0.60	0.31	0.38	0.84	0.61	0.81	0.37	0.85	0.65

^{a,b}Means within a row with different superscripts differ at $P \leq 0.05$ significance level.

¹None = healthy liver, no abscess; Mild = 1 abscess less than 2 cm in diameter to 4 abscesses less than 4 cm in diameter; Severe = 1 abscess greater than 4 cm in diameter or greater than 4 small abscesses.

²Sensory Scores: 0 = Extremely dry, tough, non, or bland; 100 = Extremely juicy, tender, abundant, or intense; 50 = neither dry nor juicy, neither tough nor tender.

a SSF kit (G-R Elec. Mfg., Manhattan, KS). An Instron testing machine (Model 5569; Instron, Canton, MA) was used in combination with a SSF blade (crosshead speed of 500 mm/min). After SSF, the remaining portion of the steak was cooled overnight at 3°C and used for WBSF. Six 1.27-cm cores, parallel to the muscle fiber orientation, were removed and sheared on the Instron testing machine with a v-blade (crosshead speed of 250 mm/min) for WBSF analysis. The values of the 6 cores were averaged to obtain a single WBSF value for each steak.

Sensory Analysis

Panelists were trained over a series of training sessions with a minimum number of 3 trainings attended over a 5-d period with a 2-d period between the end of trainings and the beginning of panels. Characteristics on which panelists were trained included initial juiciness, sustained juiciness, myofibrillar tenderness, connective tissue, overall tenderness, beef flavor intensity, and off-flavor intensity. Panelist training (19 panelists) was conducted in 8 training sessions over a 2-wk period immediately prior to sensory panel evaluation according to the Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat (American Meat Science Association, 2015). References used for the training were consistent with those described by Lucherk et al. (2016). Samples evaluated within each training session represented a large amount of variation in all sensory traits.

Anchors described by Adhikari et al. (2011) were provided at each training session and were used to set the 100 point beef flavor intensity scale. Sensory scales ranged from 0 to 100 with 0 being extremely dry, tough, none, or bland, 100 being extremely juicy, tender, abundant, or intense, and 50 being neither dry nor juicy, neither tough nor tender.

Steak samples for sensory analysis were stratified by liver score and USDA quality grade and randomly assigned to one of 20 sensory panels so that each panel had one steak from each treatment combination. Six samples were evaluated per panel with a maximum of 2 panels per d. Steaks were prepared in the same manner as described above for WBSF and SSF.

Immediately after peak temperature was reached, steaks were cut into uniform 1.3 × 1.3 × 2.5-cm cubes using a Sensory Evaluation box (G-R Elec. Mfg., Manhattan, KS) and placed into a metal double boiler to remain warm until served. Panels consisted of 20 sessions with 7 to 9 trained panelists per session. Panelists were seated in individual sensory analysis booths lit with low-intensity red and green incandescent light to mask any color differences. Unsalted crackers, apples, and deionized, distilled water were provided as palette cleansers. Digital tablet computers were used to record sensory data on each steak with each category having a continuous line scale from 0 to 100. Qualtrics analytics software (Version 2417833, Qualtrics, Provo, UT) was used to record and summarize data.

Statistical Analysis

Sensory panel, WBSF, and SSF data were analyzed using the GLIMMIX procedures of SAS (version 9.4; SAS Inst. Inc., Cary, NC). Sensory panel data were averaged within each steak and averages were used for analysis. Quality grade, liver score, and their interaction were analyzed as fixed effects and panel number was used as a random effect. Warner-Bratzler Shear Force and SSF data were analyzed with quality grade, liver score, and their interaction as fixed effects, and off peak temperature used as a covariate. A Kenward-Roger adjustment was applied to the degrees of freedom for all analyses. Significance was determined at $P < 0.05$.

RESULTS

Sensory Panel

Results for sensory panel can be found in Table 1. There were no interactions for any combination of grade \times liver score for initial juiciness, sustained juiciness, connective tissue amount, overall tenderness, beef flavor intensity, off flavor intensity, or cook loss ($P \geq 0.06$).

There was a quality grade effect for initial juiciness, sustained juiciness, connective tissue amount, overall tenderness, and beef flavor intensity ($P < 0.05$). As expected, LC steaks were greater ($P < 0.02$) for initial and sustained juiciness compared to SEL. Liver abscess score had no effect ($P > 0.70$) on initial or sustained juiciness.

There was a quality grade \times liver score interaction for myofibrillar tenderness ($P = 0.03$; Fig. 1). Within LC steaks, liver abscess score had no effect on myofibrillar tenderness ($P > 0.05$), however, in SEL steaks, M steaks were more tender than SV steaks ($P < 0.03$).

Select steaks had a greater ($P < 0.04$) amount of connective tissue than LC. Liver abscess status had no effect ($P > 0.70$) on connective tissue amount among NORM, M, or SV treatments. Liver abscess score had no effect ($P = 0.79$) on overall tenderness.

For beef flavor intensity and off flavor intensity, neither quality grade nor liver abscesses scores differed ($P > 0.26$).

Warner-Bratzler Shear Force and Slice Shear Force

Results for WBSF and SSF can be found in Table 2. There was no quality grade \times liver score interaction for WBSF values ($P = 0.38$). Neither quality grade nor liver score affected ($P > 0.08$) WBSF values. There was no interaction for quality grade \times liver score for SSF values ($P = 0.61$). Slice Shear Force was not affected by quality grade or liver score ($P > 0.38$). Cook loss was not affected ($P > 0.20$) by quality grade or liver score.

DISCUSSION

Liver abscesses are a concern in the beef industry as an economic loss to feedlots and abattoirs in addition to a possible animal welfare concern, specifically with severe abscesses (Reinhardt and Hubbert, 2015). Liver abscesses can decrease value of beef carcasses by up to \$38 per animal (Brown and Lawrence, 2010). All liver abnormalities are estimated to cost the industry more than \$15 million annually in lost liver value alone, with 67% of these abnormalities being liver abscesses (Brown and Lawrence, 2010). According to the 2011 National Beef Quality Audit liver condemnation had an incidence rate of 20.9% with 5.4% being condemned for major abscesses, 8.3% due to minor abscesses, and the remainder being for flukes, contamination, or other reasons (McKeith et al., 2012). Fortunately, results from this study indicate that liver abscesses do not effect meat tenderness or sensory attributes within LC and SEL quality grades.

Carcasses selected for this study were selected to have normal lungs with no consolidation. When liver abscesses rupture at the abattoir, all offal affected is condemned. When this occurred during this study's data collection, lungs were not able to be scored and therefore these carcasses were not included in this study. Consequently, a portion of the carcass population with SEL liver abscesses were not eligible for this study.

Product consistency is important to ensure consumer satisfaction, therefore it is necessary to understand the effect of live animal traits on meat tenderness. Beef tenderness has been identified as one of the most important buying considerations to consumers (Savell et al., 1987; Lusk et al., 2001); however, USDA quality grades are not able to explain much of the variation in beef tenderness (Smith et al., 1987). It has been well documented that chronic health problems such as bovine respiratory disease and severe liver abscesses can decrease beef yield and quality grades (Gardner et al., 1999; Brown and Lawrence, 2010). However, there is limited reported research evaluating the effects of liver

Table 2. Least squares means and SEM for effect of liver abscess score on Warner-Bratzler Shear Force, Slice Shear Force, and cook-loss for USDA Low Choice and Select beef strip loin steaks

Item	Treatments									
	Quality grade				Liver abscess score ¹					QG \times LA
	Select, <i>n</i> = 57	Low choice, <i>n</i> = 62	SEM	<i>P</i> -value	None, <i>n</i> = 43	Mild, <i>n</i> = 40	Severe, <i>n</i> = 36	SEM	<i>P</i> -value	<i>P</i> -value
WBSF ² , kg	4.53	4.22	0.13	0.09	4.42	4.34	4.35	0.17	0.91	0.38
SSF ³ , kg	28.48	26.93	0.39	0.39	29.02	26.69	27.41	1.62	0.52	0.61
Cook Loss, %	15.96	16.03	0.87	0.87	16.42	15.57	16.00	0.37	0.21	0.15

¹None = healthy liver, no abscess; Mild = 1 abscess less than 2 cm in diameter to 4 abscesses less than 4 cm in diameter; Severe = 1 abscess greater than 4 cm in diameter or greater than 4 small abscesses.

²WBSF = Warner-Bratzler Shear Force.

³SSF = Slice Shear Force.

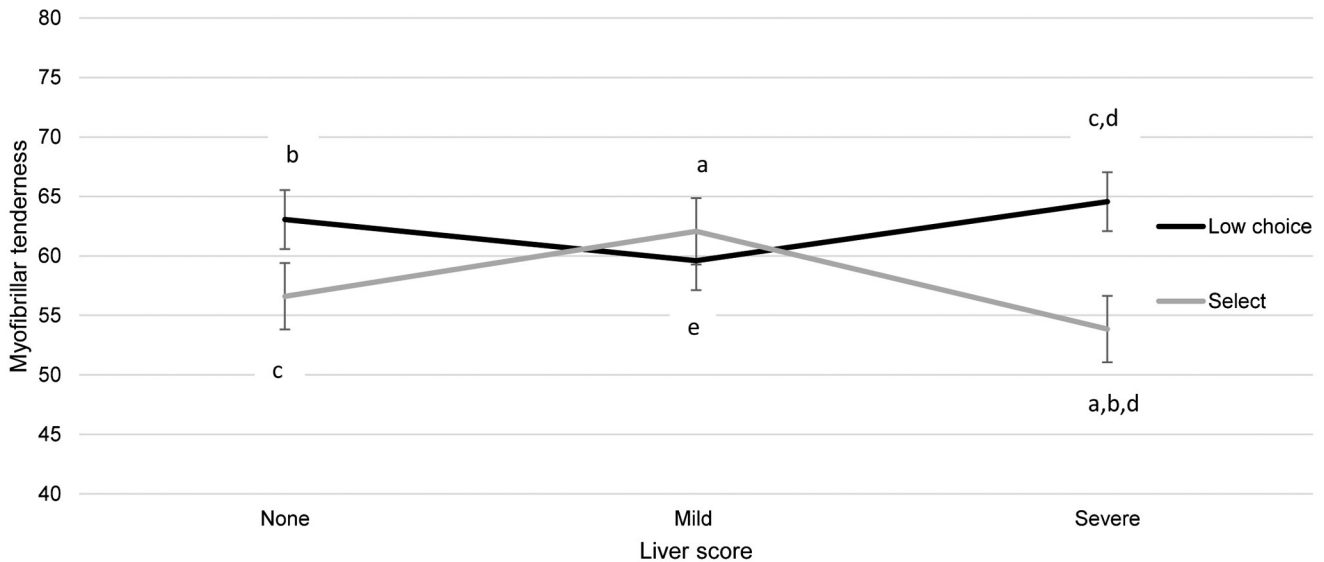


Figure 1. Least square means of effect of liver abscess score on myofibrillar tenderness by USDA quality grade for beef strip loin steaks on a continuous 1 to 100 scale. ^{a-d}Means with common letters differ at significance level of $P \leq 0.05$. Liver Score Descriptors: None = healthy liver, no abscesses; Mild = 1 abscess less than 2 cm in diameter to 4 abscesses less than 4 cm in diameter; Severe = 1 abscess greater than 4 cm in diameter or greater than 4 small abscesses Number of Observations: Low choice-none: $n = 22$; Low choice-mild: $n = 20$; Low choice-severe: $n = 20$; Select-none: $n = 21$; Select-mild: $n = 20$; Select-severe: $n = 16$.

abscesses or disease status on meat tenderness and sensory attributes. Gardner et al. (1999) reported no differences in WBSF values of LM steaks from animals with respiratory tract lesions at slaughter compared to animals without respiratory tract lesions when steaks had been aged for 14 or 21 d. However, a difference in tenderness at 7 d of aging was reported, with carcasses from animals with respiratory tract lesions having higher WBSF values when compared to their normal counterparts, but the authors indicated this difference was likely due to marbling differences within USDA quality grades between the groups. It is unknown why this tenderness difference was only observed at d 7 and not at later time points. Many studies have shown that steak tenderness increases as post-mortem aging periods increase (Martin et al., 1971; Eilers et al., 1996; Lepper-Bllilie et al., 2016). Currently, there is no standard time that beef is aged post-mortem before consumption, however the 2010 National Beef Tenderness Survey found that 21.6 d was the average post-fabrication aging period for striploins at retail establishments before consumer purchase (Guelker et al., 2013).

Brown and Lawrence (2010) reported decreased 12th-rib fat depth for all liver abscess scores compared to healthy counterparts, along with decreased hot carcass weight, yield grade, and marbling scores associated with severe liver abscesses. The results of this study and those found by Gardner et al. (1999) and Brown and Lawrence (2010) imply that infections such as respiratory disease and liver abscesses negatively affect carcass characteristics such as hot carcass weight and marbling scores, but have no effect on meat tenderness or sensory attributes.

A linear increase of beef tenderness has been shown with increasing USDA quality grades (Guelker et al., 2013; Semler et al., 2016). The 2010 National Beef Tenderness Survey found that overall, SEL steaks had greater WBSF values than LC steaks, but data specifically for strip loin steaks was not reported (Guelker et al., 2013). While this research did not find an increase in tenderness, as measured by WBSF and SSF, not all previous research has found increased tenderness with increased quality grade (Romans et al., 1965; Miller et al., 1997). Warner-Bratzler Shear Force values not differing between SEL and LC steaks is consistent with findings of Miller et al. (1997) where WBSF values were 2.39 and 2.29, respectively. This could be due to marbling being on a continuous scale, with an arbitrary boundary placed between SEL and LC, resulting in values relatively similar to one another that are in different USDA quality grades. Current USDA quality grade standards place a high value on marbling scores to determine quality grade, but variability within quality grade for beef palatability has been reported (Miller et al., 1997; Guelker et al., 2013).

Many studies have shown increased palatability traits with increased marbling scores (Wheeler et al., 1994; O'Quinn et al., 2012; Guelker et al., 2013) and is consistent with the results from the present study, where LC steaks were more desirable than SEL steaks for initial and sustained juiciness, myofibrillar tenderness, overall connective tissue amount, and overall tenderness. Increased USDA quality grade is associated with increased palatability traits, which was also in agreement with the present study. In contrast, the 2010 National Beef Tenderness Survey found no dif-

ferences in palatability traits when comparing USDA SEL and LC loin steaks (Guelker et al., 2013).

Warner-Bratzler Shear Force values and SSF values were relatively high for this study compared to other studies in these quality grades. The cause of this trend is unknown, but is most likely attributed to pre-slaughter effects such as genetic or other factors outside of the scope of this project. The shear force values in this study were higher than expected; however, values for WBSF and SSF were consistent with other published research (Acheson et al., 2014; Semler et al., 2016). Acheson et al. (2014) found that USDA slight marbling scores, equivalent to the SEL group in the study at hand, and USDA small marbling scores, equivalent to the LC group in the present study, had average WBSF values of 4.55 kg and 4.17 kg, respectively. Warner-Bratzler Shear Force and SSF values were consistent with one another for steaks.

Conclusion

The data suggest that liver abscesses do not impact meat tenderness, flavor, or other sensory attributes within quality grade. This is beneficial knowledge for the livestock and meat industries given the current high prevalence of liver abscesses. In the future, it is possible that some liver abscess prevention methods, such as tylosin phosphate may be more heavily regulated. Other liver abscess preventions are currently being investigated, but none are currently widely used in the cattle feeding industry. While many of the ramifications of removing tylosin phosphate from finishing rations are unknown, it is now known that meat tenderness will not be impacted if prevalence of liver abscesses increases.

Although there were no differences in meat tenderness due to liver abscess score, liver abscesses still have a significant impact on margins in the beef industry due to decreased feedlot performance and marbling. Research on liver abscess prevention without the aid of antimicrobials is still warranted. Further possible extensions of this work include the effect of other animal health concerns on meat quality and length of post-mortem aging on tenderness differences due to liver abscesses.

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