2023

Effect of increasing corn silage inclusion in finishing diets cattle with or without tylosin on performance and liver abscesses

Hannah C. Wilson

Levi J. McPhillips

Bradley M. Boyd

Andrea K. Watson

Jim C. MacDonald

See next page for additional authors

Authors

Hannah C. Wilson, Levi J. McPhillips, Bradley M. Boyd, Andrea K. Watson, Jim C. MacDonald, and Galen E. Erickson

Effect of increasing corn silage inclusion in finishing diets cattle with or without tylosin on performance and liver abscesses

Hannah C. Wilson, Levi J. McPhillips, Bradley M. Boyd, Andrea K. Watson, Jim C. MacDonald, and Galen E. Erickson

Department of Animal Science, University of Nebraska–Lincoln, Lincoln, NE 68583, USA

Corresponding author — Galen E. Erickson, gerickson4@unl.edu

Abstract

A pooled analysis was performed to evaluate whether corn silage fed at 15% or 45% of diet DM impacted liver abscesses prevalence at slaughter in five previous experiments. Cattle fed 15% corn silage had 7.8% abscessed livers compared to 4.1% for cattle fed 45% corn silage when all diets contained tylosin. While improved due to increased corn silage inclusion, the objective of the current finishing study was to determine the impact of silage inclusion in finishing diets with and without tylosin on performance and incidence of abscessed livers in beef cattle. A total of 640 (BW = 334 ± 25 kg) steers were used in a generalized randomized block design with a 2 × 2 factorial treatment design. Treatments included two concentrations of corn silage (15% and 45% of

Published in *Journal of Animal Science* 101 (2023), 12 pp.
doi:10.1093/jas/skac380

Submitted July 14, 2022; accepted November 17, 2022; published 3 January 2023.

diet DM), with or without tylosin for liver abscesses. This study used 32 pens of cattle with 20 steers per pen and 8 pens per treatment. There was a tendency for an interaction for feed efficiency (G:F; $P = 0.10$) where cattle fed 15% corn silage had a 2% increase in G:F when tylosin was added to the diet, but no improvements in G:F were observed when tylosin was added to diets containing 45% silage. There was an interaction between silage and tylosin inclusion for abscessed livers ($P = 0.05$). Cattle fed 15% corn silage without tylosin had the greatest incidence of abscessed livers (34.5%) compared to other treatments ($P = 0.05$), and the incidence of abscessed livers was decreased to 19% if tylosin was fed with 15% corn silage. Feeding 45% silage was effective at lowering the incidence of abscessed livers ($P = 0.05$) which was 12.4%, regardless of whether tylosin was fed. Feeding corn silage at 45% of diet DM (77.5% concentrate) was as effective as feeding tylosin to cattle on a 92.5% concentrate diet. Feeding corn silage at greater inclusions decreased daily gain ($P \leq 0.01$) but increased final body weight when fed to an equal fatness (cattle fed 45% CS were fed 28 d longer). Feeding corn silage at 45% was more economical compared to feeding 15% corn silage, especially as corn prices increase, provided shrink is well managed. Feeding elevated concentrations of corn silage may be an economically viable method to reduce incidence of liver abscesses without antibiotic use for smaller operations that can manage more corn silage in finishing diets.

Lay Summary

Antibiotics are a very effective method to control liver abscesses for finishing cattle, which are thought to be due to high starch concentration and acidosis. Dietary roughage (forage) is used to control acidosis. As grain prices increase, feeding greater amounts of corn silage may be advantageous and silage can be an economical forage compared to other traditional forages like alfalfa. This study evaluated the impact of corn silage inclusion on performance and abscessed livers with and without the addition of antibiotics. As expected, feeding more corn silage decreased both gain and feed efficiency but also increased profitability. Feeding tylosin with a traditional inclusion of silage (15%) decreased abscessed livers from 34.5% to 19%. However, if cattle are fed more silage (45%) the incidence of abscessed livers was 12.4%, regardless of feeding tylosin or not.

Keywords: antibiotics, corn silage, feedlot cattle, liver abscesses, roughage, tylosin

Abbreviations:

ADG	average daily gain
AL	abscessed livers
BW	body weight CS corn silage
CYG	calculated USDA Yield Grade
DGS	distillers grains plus solubles
DM	dry matter
DMI	dry matter intake
DRC	dry-rolled corn
ENREEC	Eastern Nebraska Research, Extension, and Education Center
G:F	gain to feed

HCW	hot carcass weight
HMC	high-moisture corn
LM	longissimus muscle
MDGS	modified distillers grains plus solubles
NDF	neutral detergent fiber
WDGS	wet distillers grains plus solubles

Introduction

Approximately 40% to 45% of feedyard cattle are finished in Nebraska, Iowa, and Kansas (USDA, 2021). Corn silage is a common feed ingredient used in many growing and finishing beef operations. Because of its versatility, corn silage can be fed at many different concentrations in a ration leading to varying degrees of economic advantages and cattle efficiencies (Hilscher et al., 2019; Ovinge et al., 2019). It can be economically beneficial for cattle feeders with access to corn, who also have ownership of fed cattle, to use their corn crop as a feedstuff (corn silage) and realize profits in the form of pounds of beef. When corn has been relatively expensive ($5 to $7/25.4 kg), it has been shown that corn silage can partially replace corn as an energy source in finishing diets (Burken et al., 2017b; Hilscher et al., 2019). Feeding corn silage allows cattle feeders to take advantage of the entire corn plant at a time of maximum quality and tonnage as well as secure substantial quantities of roughage and grain inventory (Burken et al., 2017b). This system-based approach integrates and optimizes corn acres while having a significant economic impact on cattle feeding (Ovinge et al., 2019). Increasing corn silage by replacing corn grain decreases gain to feed (G:F) and lowers average daily gain (ADG) of cattle but can still be economical (Burken et al., 2017a). Examining the input costs and subsequent revenue based on feed ingredients is critical for understanding the profitability of an operation, warranting a closer look at the economic viability of diets containing high concentrations of corn silage.

It has been well established that increasing roughage concentration in high concentrate diets reduces the risk of acidosis, bloat, and liver abscesses resulting from feeding highly fermentable carbohydrates (Owens et al., 1998). Traditional sources of roughage like alfalfa and grass hay can pose problems for feedyards due to bulk size and increased cost per unit of energy. Corn silage is one possible alternative. However, with the high starch concentration of corn silage compared to other traditional roughages, especially in diets containing distillers grains, the effect of inclusion level on liver abscesses is not well understood. The veterinary feed directive requires a prescription for antibiotics that are considered medically important classes of antibiotics, such as macrolides (tylosin), when used in finishing diets to decrease the incidence of liver abscesses. To reduce the use of antibiotics and the need for veterinary approval, there is interest in natural alternatives (additives or dietary interventions) for the prevention and control of liver abscesses, but these alternatives must be efficacious. The interaction between corn silage as a roughage source and the use of tylosin and how it affects liver abscesses is not well understood. Diluting the energy and readily available starch concentration of the diet by increasing the amount of corn silage may have a positive effect on the incidence of liver abscess without the use of antibiotics. The first objective of this project was to determine if greater concentrations of corn silage led to a decrease in abscessed livers in previously conducted trials, all containing tylosin with cattle fed the same number of days on feed. Using that information, the second objective was to determine if corn silage could be used without tylosin to reduce the incidence of abscessed livers. Lastly, this study aimed to explore the economic impacts of feeding corn silage at two concentrations in diets with distillers grains when cattle were fed to a common fat endpoint, with and without tylosin.

Materials and Methods

All procedures used in the pooled analysis and published experiments were reviewed and approved by the University of Nebraska–Lincoln Institutional Animal Care and Use Committee. The finishing experiment included in this manuscript also used procedures reviewed and approved by the University of Nebraska–Lincoln Institutional Animal Care and Use Committee (IACUC #1785).

Pooled analysis

Prior to a live animal study, a pooled analysis was conducted to investigate the interactions between corn silage concentration and abscessed livers. The pooled analysis consisted of data from 5 feeding trials (122 pens; 1116 cattle) conducted at the University of Nebraska-Lincoln at the Eastern Nebraska Research Extension and Education Center (ENREEC) near Mead Nebraska (Burken et al. 2017a, 2017b; Ovinge et al., 2019; Hilscher et al., 2022). A brief summary of experiment variables is given in **Table 1**. These trials contained treatments with 15% and 45% corn silage inclusions, all containing tylosin, and the incidence of abscessed livers was measured. Additionally, trials evaluated varying levels of distillers grains inclusions. Other variables included length of trial (feeding to a common end point or common days on feed), number of cattle per pen, and formulation of tylosin inclusion.

For the pooled analysis, only pens receiving 15% and 45% corn silage were considered and hybrid was ignored. In all studies, livers were evaluated after evisceration and categorized from 0 (no abscesses), A−, A, or A+ (severely abscessed) according to the procedures outlined by Brink et al. (1990). Because of low overall incidence, severity scores were combined and assessed as having an

Table 1. Major experimental variables among studies used in a pooled analysis to determine the interaction of corn silage concentration and the incidence of abscessed livers

	Ovinge et al., 2019	*Hilscher et al., 2022*	*Burken et al., 2017a*	*Burken et al., 2017a*	*Burken et al., 2017b*
Location	ENREEC	ENREEC	ENREEC	ENREEC	ENREEC
Year	2017	2015	2013	2012	2011
Length, d	153–181	181	91, 98	134, 148	173
Cattle type	Angus crossbred	Angus crossbred	Angus crossbred	Angus crossbred	Angus crossbred
Sex	Steer	Steer	Steer	Steer	Steer
Initial BW, kg	318	334	468	348	324
Tylosin, mg/steer daily	91	90	90	90	90
Animals per pen	8	10	9,10	9	9
Pens per treatment	6	6	6	5	6
Experimental Design[1]	GRBD	GRBD	RCBD	GRBD	GRBD
# treatments	6	6	5	5	6
Silage concentrations	15, 45	15, 45	15, 45	15, 45	15, 45
Distillers grains inclusion	21	20	20, 40	20, 40	40

1. GRBD, generalized randomized block design; RCBD, randomized complete block design.

abscess (A−, A, and A+) or no abscess (0). Due to the nature of separately conducted trials, the individuals scoring livers would have been independently trained individuals.

Data were analyzed using the PROC GLIMMIX procedures of SAS (SAS Institute, Inc., Cary, NC) utilizing a binomial distribution for liver scores (abscess or no abscess). Pen was the experimental unit with body weight (BW) block within experiment used as a fixed effect. Silage level, DGS level, trial, and all interactions, including a 3-way interaction (silage level × DGS level × trial) were included in the model. An α level of $P \leq 0.05$ was used to determine significance, and a tendency was declared at $0.10 \leq P \geq 0.05$. The data generated from the pooled analysis was used to justify an additional live animal study to further investigate the interaction between feeding different concentrations of corn silage and the incidence of abscessed livers when cattle were not fed tylosin.

Finishing experiment

Corn silage was harvested at ENREEC near Mead, Nebraska, between August 27 and 31, and on 10 September 2018. Corn silage harvest was initiated when the field was approximately ¾ milkline and 37% DM. Dry matter samples were taken from each truckload of corn silage and dried in a 60 °C forced-air oven for 48 h to determine DM of the silage at harvest. Silages were stored in a sealed agricultural bag (AgBags, St. Nazianz, WI), opened after 21 d, and sampled to determine DM (forced-air oven at 60 °C). All feeds were sampled weekly for DM, and monthly composites were analyzed for nutrient composition.

Upon receiving (October 19 to 31), all steers received internal parasite drench (SafeGaurd Drench, Merck Animal Health, Madison, NJ), vaccinations for bovine rhinotracheitis virus, bovine viral diarrhea caused by bovine virus diarrhea virus Types 1 and 2, and disease caused by parainfluenza 3 virus and bovine respiratory syncytial virus (Bovi-Shield Gold 5, Zoetis, Parsippany-Troy Hills, NJ), prevention for clostridial diseases (Ultrabac-7; Zoetis), intranasal respiratory vaccine that prevents respiratory disease caused by BRSV (Inforce 3; Zoetis), and internal and external parasites of cattle (Dectomax injection; Zoetis). Cattle were revaccinated on November 5th or 12th (blocks 1 and 2, respectively) against respiratory viruses (bovine rhinotracheitis virus, bovine virus diarrhea virus 1 and 2) and *M. haemolytica* (Bovi-Shield Gold One Shot; Zoetis), and *Histophilus somni* (Somubac; Zoetis).

Approximately 670 newly received cattle were individually weighed prior to the initiation of the study using a hydraulic squeeze chute (Silencer, Dubas Equipment, NE). Cattle on the ends of the distribution were removed so that weight blocks could be easily distributed. Blocking criteria was assessed based on the population distribution and that blocks would be less than 45 kg in range. Six hundred and forty, crossbred, calf-fed (<1 year old; initial BW 293 ± 13.6 kg) steers were sorted into 2 BW blocks and assigned randomly to pens (20 steers/pen) within starting week and block. Treatments were then assigned randomly to pen. Bunks were 6.1 to 9.8 m, averaging 39.6 cm (30–48 cm) of bunk space per steer which is considered industry recommendation (Harner and Murphy, 2021). To be able to measure differences in the incidence of liver abscesses, it is important to have a population of cattle in an environment inducive of producing liver abscesses. The study was designed with 20 steers per pen to have steers receive similar feeding competition as they would in a commercial feedlot, and thus develop similar incidence of liver abscesses. Cattle were started at two time points starting on November 20 for block 1 and November 30 for block 2 due to number of steers to weigh and sort by days. Within each block, one heavy replication and 3 light weight replications were started each week. The heavy block averaged 312–320 kg and the light block weighed 282–291 kg. In the final analysis, the light block included 2 replications, and the heavy block included 6 replications per treatment, and initiation week was not included as a blocking factor as it was insignificant.

All steers were limit-fed a common diet of 50% alfalfa hay and 50% Sweet Bran (Cargill Corn Milling, Blair, NE) at 2% of BW for 5 d before the initiation of the trial to minimize gut fill. Initial BW was measured on two consecutive days and averaged using a hydraulic squeeze chute suspended on a load cell scale. Diet adaptation strategies differed by treatment. Adaptation diets included 20% modified distillers grains plus solubles (MDGS) and 45% corn silage for the 45% corn silage treatments with 19% alfalfa and 4%

supplement (with or without tylosin). A 60:40 blend of high moisture corn (HMC) and dry rolled corn (DRC) was increased from 12% to 30% by replacing alfalfa in 3 steps over 14 d. For the 15% corn silage treatment, adaptation diets began with 20% MDGS, 5% supplement, and 15% corn silage. A 60:40 blend of HMC:DRC increased from 20% to 60% by replacing alfalfa hay in 5 steps over 21 d. Feed was delivered once a day, in the morning, to concrete fence-line feed bunks with a Roto-Mix model 420 (Roto-Mix, Dodge City, KS) mixer/delivery box mounted on a single-axle feed truck. A water-soluble artificial blue dye allowed by the FDA for use in foods (FD & C Blue Dye) was used to identify correct delivery of supplement, ensuring no animals on the control groups (no tylosin) received tylosin by accident. This gave the supplement a blue color which was visually apparent when delivered to the feed bunk. Trucks were cleared with a “washout” load in between any loads that contained tylosin and the control loads with no tylosin.

Treatments were arranged as a 2 × 2 factorial, that consisted of two inclusions of corn silage (15% or 45% DM), with or without tylosin (**Table 2**). The four treatments were 15% corn silage without tylosin (CS15), 45% corn silage without tylosin (CS45), 15% corn silage with tylosin (TCS15), and 45% corn silage with tylosin (TCS45). All steers were fed monensin (Rumensin, Elanco Animal Health, Greenfield, IN) at 33 mg/kg of DM and tylosin phosphate (Tylan; Elanco Animal Health) was included at 9.7 mg/kg of DM.

Steers were implanted with 80 mg of trenbolone acetate and 16 mg estradiol (Revalor-IS; Merck Animal Health) on d 1 and then implanted again with 200 mg of trenbolone acetate and 20 mg estradiol (Revalor-200; Merck Animal Health) on day 75 and 85 for blocks 1 and 2, respectively. Cattle being fed 15% corn silage were transported to the abattoir on May 28th after 185 d on feed. To achieve similar fatness, cattle fed 45% corn silage were transported 4 wk later, on June 25th after 213 d on feed. Images were acquired using an Aloka SSD-500V (Hitachi Healthcare Americas) and were processed by The Cup Lab (Ames, IA). Two pens of cattle from each block within treatment were observed by ultrasound on day 157.

On the morning of transportation, cattle were fed . of their dry matter intake (DMI) from the previous day and weighed at the

Table 2. Composition (% of diet DM) of dietary treatments fed to calf-fed steers with or without tylosin

Ingredient	*Treatment*[1]			
	CS15	*CS45*	*TCS15*	*TCS45*
High-moisture corn	36.6	18.6	36.6	18.6
Dry-rolled corn	24.4	12.4	24.4	12.4
Corn silage	15	45	15	45
MDGS	20	20	20	20
Supplement[2]				
Fine ground corn	1.3555	1.3555	1.3675	1.3675
Limestone	1.64	1.64	1.64	1.64
Urea	0.5	0.5	0.5	0.5
Salt	0.3	0.3	0.3	0.3
Tallow	0.1	0.1	0.1	0.1
Beef trace minerals premix[3]	0.05	0.05 0.05	0.05	
Rumensin premix[4]	0.0165	0.0165	0.0165	0.0165
Vitamin A-D-E premix[5]	0.015	0.015	0.015	0.015
Tylosin premix[6]	–	–	0.011	0.011
Water	0.021	0.021	–	–
FD&C #1 Blue dye[7]	0.002	0.002	–	–
Nutrient Composition, % DM				
Crude Protein	14.5	14.3	14.5	14.3
Neutral Detergent Fiber	15.6	23.6	15.6	23.6
Acid Detergent Fiber	7.34	13.3	7.34	13.3

1. Treatments included CS15, Corn silage included at 15% of diet DM without tylosin; CS45, Corn silage included at 15% of diet DM without tylosin; TCS15, Corn silage included at 15% of diet DM with tylosin; TCS45, Corn silage included at 15% of diet DM with tylosin.
2. Supplement fed at 4% of dietary DM for all treatments.
3. Trace mineral premix contained 6% Zn, 5.0% Fe, 4.0% Mn, 2.00% Cu, 0.29% Mg, 0.2% I, and 0.05% Co.
4. Formulated to supply Rumensin-90 (Elanco Animal Health) at 33 mg/kg DM.
5. Vitamin A-D-E premix contained 30,000 IU of vit A, 6,000 IU of vit D, 7.5 IU of vit E per gram.
6. Formulated to supply Tylan-40 (Elanco Animal Health) at 9.7 mg/kg DM.
7. FD & C Blue Dye: water-soluble artificial blue dye allowed by the FDA for use in foods; was used to identify correct supplement delivery.

feedyard approximately 7 h post feeding before being loaded onto trucks. All pens of cattle were weighed in groups of up to 8 steers on a portable group livestock scale on the day of transportation to calculate dressing percentage. To determine treatment means, the average live final BW (with 4% shrink applied) for each pen was used to calculate an average dressing percent for that pen with the pen average carcass weight. However, a common dressing percentage of 63% was used to calculate all carcass adjusted performance responses.

Steers were transported in the evening and harvested at a commercial abattoir (Greater Omaha Packing Co., Omaha, NE) the following morning. On the day of harvest, hot carcass weight (HCW) was recorded, and carcass-adjusted final BW was calculated from a common 63% dressing percentage. The carcass adjusted final BW was used to determine ADG and G:F. On the day of harvest, liver scores were recorded immediately following evisceration. The scoring system used was as follows: 0, no liver abscesses; A−, one or very few small abscesses; A, 1 large abscess or a few small abscesses; A+, many large abscesses (Brink et al. 1990). The data were considered missing if the carcass was railed out before reaching evisceration and the liver could not be viewed. Two trained individuals scored each individual liver, where the unanimous score or the lower value was used if there was a discrepancy. Carcass order was random, and treatments were not known at the time of scoring. Carcass characteristics, recorded after a 48-h chill, included marbling score, 12th rib fat thickness, and LM area. Quality grades were based on the marbling score (300 to 399 Select, 400 to 499 low choice, 500 to 699 upper choice, and >700 as prime). Calculated yield grade was calculated using 2.50 + (6.35 × fat thickness, cm) + (0.2 × KPH, %) + (0.0017 × HCW, kg) − (2.06 × LM area, cm^2).

Two ancillary analyses were conducted to try to further illustrate how the severity of an abscessed liver may impact the total growth of the animal subsequently having a smaller ending carcass weight. In both analyses, cattle were grouped into groups based on carcass weight with 15 kg separating each group. In the first analysis, the percentage of abscessed livers, categorized by severity, were compared at each weight increment. In the second analysis the cumulative percentage of abscessed livers, categorize by severity, were compared at each weight increment. For example, if 50% of severely abscessed livers (A+) were found in carcasses less than 350 kg, it may suggest some type of correlation (but not causation) between severe abscesses and low carcass weights.

Feed samples were collected weekly, weighed, and then dried in a 60 °C forced-air oven for 48 h to determine DM concentration (AOAC, 1999; method 934.01). Dried feed samples were ground with a Wiley mill (Thomas Scientific, Swedesboro, NJ) through a 1-mm screen and composited by month. Crude protein, neutral detergent fiber, and acid detergent fiber were determined on the trial composite sample by Ward Laboratories (Kearney, NE). Ash and OM were measured by placing crucibles containing 0.5 g of each feed sample in a muffle furnace for 6 h at 600 °C (AOAC, 1999; method 942.05).

Corn silage economics

Volatility in the commodity market can make the economic incentive to feed a certain ingredient more or less favorable depending on the current price. Understanding the input costs and resulting performance of using an ingredient is essential to a profitable operation. An economic assessment of corn price, cattle price, and other economic factors were considered in an economic analysis to better understand the utility of feeding greater concentrations of corn silage in finishing diets. The following calculations used local feed source values, yardage and opportunity cost, and other values common for the state of Nebraska. These tools would be best utilized by altering the user inputs to more closely reflect that of your location and operation. The following numbers are to help represent a common scenario for feedlot producers in the central Midwest. The inputs used for the calculations are briefly described in **Table 3**.

The cost of corn silage is directly related to the price of corn. This analysis used a dry corn price of $3.67/25.4 kg. Corn silage price was calculated using Iowa State University's corn silage pricing application (Edwards and Loy, 2017). Corn silage was priced at $39.91 per metric tons as-is ($107.89/metric ton DM, 37% DM). The following inputs for expected production were 24.28 ha and 59.2 metric tons of silage (37% DM) per hectare (based on expected corn yield with 6% yield drag). The opportunity cost of harvesting and selling corn stover as well as the cost to replace phosphate and potash after stalk removal was subtracted. Total replacement is estimated at 1.75 kg phosphate/metric ton and 4.52 kg potash/metric ton (Edwards and Loy, 2017). A credit was given for manure value. Manure credit was assessed as spreading 1 out of

Table 3. Expected production, inputs, and opportunity costs used for calculating the cost of harvesting and feeding corn silage

Item	*Production costs*
Expected production	
Expected Yield, ha (grain DM = 50% of total)	>24
Estimated % moisture for corn silage when harvested	63%
Actual silage yield, metric ton/acre, 6% yield drag	59.2
Corn stover produced, metric ton	4.12
Phosphate fertilizer to replace stalks removed (kg/metric ton harvested)	0.16
Potash fertilizer to replace stalks removed (kg/metric ton harvested)	0.11
Harvesting costs	
Corn price, $/25.4 kg, September Price	$3.67
Grass hay, $/metric ton	$90.72
Cost of phosphate fertilizer ($/kg; from above)	$0.15
Cost of potash fertilizer ($/kg; from above)	$0.11
Grain and stover harvesting, $/ha (includes combining)	$29.29
Hauling and storing, $/metric ton	$1.00
Value based on opportunity cost to seller ($/metric ton of silage)	
Lost gross revenue from not harvesting corn grain	$26.17
Lost gross revenue from not harvesting corn stover	$3.68
Fertilizer cost for nutrient removal if harvested as silage	$1.68
Manure nutrient replacement from silage (added value)	−$2.57
Manure Spread Cost (45% corn silage diet)	$0.82
Drying and storage costs savings for corn grain and stover	−$3.42
Equals opportunity cost of selling silage in the field	$25.54
Harvesting and storage costs for silage	$11.70
Shrink of Silage (15% DM shrink)	$4.51
Opportunity cost of selling stored silage	$38.49
Feed value of silage (as− is; 37% DM)	$39.92
Ingredient and processing costs	
Corn Silage, calculated from above ($/metric ton DM)	$107.89
MDGS ($/metric ton DM)	$125.93
DRC ($/metric ton DM)	$139.93
DRC processing ($/metric ton DM)	$1.97
Supplement ($/metric ton DM)	$272.23
Animal processing ($/animal)	$20.00
Tylosin (if included; $/animal daily)	$0.01
Yardage ($/animal daily)	$0.50
Initial Purchase Price ($/45.4 kg)	$1.66
Sale Price ($/45.4 kg)	$1.20

Values derived from corn silage pricing application (Edwards and Loy, 2017) and The Beef Feed Nutrient Management Planning Economics (BFNMP$).

MDGS, wet distillers grains plus solubles; DRC, dry rolled corn.

every 4 yr in a rotation to provide enough phosphorus for 4 yr. The value of manure was calculated using The Beef Feed Nutrient Management Planning Economics (BFNMP$) tool using 45% silage-based diet with 20% WDGS, adding up to a total value of $12.48/metric ton of silage intake (Koelsch, 2013).

Local feed values and processing costs were used for the rest of the ingredients. Briefly, high moisture corn was priced relative to corn accounting for 30% moisture and adding processing costs and 5% moisture discount. The cost of MDGS was set at 90% the price of corn (DM basis) including 5% shrink. A 1% shrink was applied to supplement costs. Supplements containing tylosin were charged an additional $0.01/ steer daily. Feed interest (7.5%) was applied to half of the total feed amount for the entire feeding period. Medicinal and processing charges were $20/steer and yardage was charged as $0.50/steer daily.

Cattle interest costs were set at 7.5% of the initial purchase price over the feeding period (Days on feed/365) including an additional $200 deposit. A 5-year average (May 2014–May 2019) for feeder price in Nebraska ($1.3952/45.4 kg; Livestock Marketing Information Center) was used to target a net return of $0/steer for cattle on the 15% silage treatment. Returns were calculated as the difference in gross inputs and revenues where values represented profit in dollars per steer ($/steer) and were calculated using final BW with a 63% common dressing percent.

Mortality and animals removed for chronic sickness (less than 6 animals total) were considered by removing that animal from the total head per pen on the day of removal. The purchase cost and interest of the animal remained toward the total costs, but the animal was not charged feed inputs over the remaining days after removal. There was no revenue added for that animal.

A sensitivity analysis, for changes in corn price, was conducted where returns were calculated as the difference in gross inputs and revenues where values represented profit in dollars per steer ($/steer). A specific net return was targeted to assess a break-even operation. Corn silage prices changed with the price of corn. Corn silage (at 37% DM) price compared to $3.00, $4.00, and $5.00/25.4 kg (bu) corn was $35.24 (per metric tons as is, 37% DM), $38.70, $42.25, respectively. Returns were calculated using a single 5-year average for live fed price for Nebraska ($1.2500/45.4 kg). However, feeder price decreased with increasing corn price to achieve breakeven ($0 net return) for the 15% corn silage treatment. Total feed costs included processing and shrink identical to the scenarios above. Cattle interest, feed interest, cattle processing, and yardage remained static following the description above.

Carcass performance data were analyzed using the PROC MIXED procedures of SAS (SAS Institute, Inc., Cary, N.C.) as a randomized block design with pen as the experimental unit and block as a fixed effect. The experiment was analyzed as a 2 × 2 factorial with two inclusions of corn silage (15 or 45) and with or without tylosin. Liver abscess incidence was analyzed using PROC GLIMMIX of SAS with the outcome of interest as the number of steers affected out of the total number of steers within the pen as binomial variables. Yield grade, quality grade, and liver abscess severity were analyzed using PROC GLIMMIX of SAS using a multinomial distribution to evaluate distribution differences due to treatment. Liver abscess category, treatment, and the interaction between liver abscess category and treatment were used as fixed effects. For all analysis, Type III sums of squares and least square means were used with an α level of $P \leq 0.05$ and a tendency was declared at $0.10 \leq P \geq 0.05$. If the interaction was significant, then simple effect means were compared using a pair-wise *t*-test. If no significant interactions were detected, then main effect means were compared using an *F*-test for 2 treatment factors.

Results and Discussion

Pooled analysis

The initial model yielded no significant trial × distillers grains (DGS) level × silage level interaction ($P \geq 0.15$), and no interaction for trial × silage level or trial × DGS level ($P \geq 0.28$). Additionally, there was no interaction for silage level × DGS level ($P = 0.96$). Therefore, only main effects will be discussed. Overall, 69 cattle out of 1116 (6.18%) had abscessed livers which varied by study ranging from a study average of 2.8% to 13.4% incidence of abscessed livers, which is lower than industry average (12% to 32%) in the United States (Davis et al., 2007). Because of the low incidence (all diets included tylosin), it was difficult to determine the distribution in severity of the abscessed livers.

In this analysis, inclusion of distillers grains included 20% and 40% of diet DM, but were not equally represented in number of pens across trials. Distillers grains concentration had no effect on the incidence of abscessed livers ($P = 0.59$). Conflicting results on the inclusion of distillers grains and liver abscesses have been previously reported. Meyer et al. (2013), replaced 25% of the diet as dry-rolled corn with distillers grains and observed no difference in the incidence of abscessed livers. On the contrary, He et al. (2014) reported an increase in abscessed livers, from 15% to 49%, when 30% of the diet replaced rolled barley with distillers grains. Depenbusch et al. (2008) observed no difference in overall percentages of abscessed livers with the inclusion of tylosin and the inclusion of 25.5% (% DM) distillers grains in a steam-flaked corn diet. There was a significant effect of silage level on the incidence of abscessed livers ($P = 0.01$; **Table 4**). Cattle fed 45% corn silage had an average of 4.1% abscessed livers, compared with 7.8% for cattle fed 15% corn silage.

Finishing experiment

By design, all cattle were fed to a similar 12th rib fat thickness ($P \geq 0.10$) to ensure equal degree of finish when comparing performance and carcass characteristics. Based on previous data by Ovinge et al. (2019), cattle fed 45% corn silage for 4 more weeks

Table 4. Main effect of corn silage inclusion on the incidence of abscessed livers in finishing steers across 5 research trials*

Corn silage inclusion, % DM	*AL*[†]*, n*	*Total cattle, n*	*AL, %*
15	44	531	7.80
45	25	531	4.12

* Trials used in the pooled analysis: 1) Ovinge et al. (2019); 2) Hilscher et al. (2022); 3, 4) Burken et al. (2017a); 5) Burken et al. (2017b); $P \leq 0.01$ SEM = 2.3; CS × DGS interaction: $P \geq 0.56$

† AL, abscessed livers

compared to cattle fed 15% corn silage, achieved similar back fat thickness at harvest. This information was corroborated with ultrasound during the current trial as described above (data not shown). When cattle fed 15 CS were harvested at 185 d, back fat thickness progression was used to project the remaining cattle fed 45 CS. Cattle fed 45 CS were fed for 213 d and 15 CS were fed for 185 d (**Table 5**). There was a tendency ($P = 0.10$) for backfat to differ between silage inclusions, but the difference in means was less than 0.045 cm (SEM = 0.01) of back fat, which is not biologically meaningful.

There was a tendency for an interaction for G:F ($P = 0.10$; Table 5). Cattle fed 15% CS with tylosin (15TCS) had the greatest G:F, 15% corn silage without tylosin (15CS) was intermediate, and both 45% corn silage with and without tylosin (45CS and 45TCS) had the poorest G:F. However, in cattle fed 45% silage, no improvements in G:F were observed when tylosin was added to the diet. Muller et al. (2018) reported no differences for final BW, ADG, DMI, or G:F for cattle fed a 58% steam flaked corn, 10% corn silage diet, between cattle that received 9.9 mg/ kg of tylosin, no tylosin, or intermittent doses of tylosin (1 wk on, 2 wk off). Other studies have reported minimal to no effects of the addition of tylosin on performance (Brown et al., 1975; Potter et al., 1985). However, Meyer et al. (2009) reported improved G:F when tylosin was included in a HMC based diet.

There were no differences observed in initial BW ($P = 0.97$). There were no interactions for live final BW, carcass adjusted final BW, HCW, DMI, or ADG ($P \geq 0.21$).

There was no effect of silage inclusion on LM area, marbling, or dressing percentage (**Table 6**; $P \geq 0.15$). Calculated yield grade (CYG) was greater for cattle fed 45% corn silage ($P < 0.01$). Hilscher et al. (2019) observed no differences in LM area or marbling score when cattle were fed 15% or 45% corn silage but with cattle fed the same number of days. However, Burken et al. (2017a) reported improved marbling for steers fed 45% corn silage compared to steers fed 15% corn silage but reported no differences in calculated yield grade. Conversely, Ovinge et al. (2019) observed no difference in marbling scores but reported greater LM areas for cattle fed 45% corn silage, but with 28 d longer on feed.

Table 5. Simple effects for carcass adjusted performance of cattle fed 15% or 45% corn silage with or without tylosin

	Treatment[1]				*SEM*	*P-value*[2]		
	− Tylosin		*+ Tylosin*					
	CS15	*CS45*	*TCS15*	*TCS45*		*Tylosin × Silage*	*Tylosin*	*Silage*
Days on Feed	185	213	185	213	–	–	–	–
Initial BW, kg	294	294	293	294	4.86	0.97	0.94	0.97
Live final BW, kg	583	607	588	609	6.64	0.77	0.60	<0.01
Carcass adjusted performance[3]								
Final BW, kg	582	607	589	604	7.32	0.51	0.82	0.01
DMI, kg/d	9.9	10.5	9.9	10.5	0.11	0.94	0.86	<0.01
ADG, kg	1.56	1.47	1.60	1.46	0.02	0.21	0.55	<0.01
G:F	0.158b	0.140c	0.162a	0.139c	0.0015	0.10	0.27	<0.01
Return, $/steer	−9.57	13.43	9.61	7.39	8.33	0.14	0.44	0.22
Carcass characteristics								
HCW, kg	367	382	371	380	4.64	0.53	0.84	0.01
LM area, cm^2	89.7	89.0	89.7	87.7	0.90	0.53	0.53	0.18
12th rib fat, cm	1.22	1.24	1.17	1.24	0.04	0.50	0.69	0.10
Marbling[4]	456	446	440	445	7.14	0.33	0.25	0.69
CYG[5]	2.82	3.01	2.83	3.07	0.05	0.60	0.54	<0.01
Dressing, %	63.2	63.2	63.3	62.7	0.14	0.20	0.33	0.15
Abscessed livers[6]	34.5a	12.0b	19.2b	12.7b	5.55	0.05	0.09	<0.01

a, b, c Means within rows with different superscripts differ ($P \leq 0.05$).

1. Treatments included CS15, Corn silage included at 15% of diet DM without tylosin; CS45, Corn silage included at 15% of diet DM without tylosin; TCS15, Corn silage included at 15% with tylosin; TCS45, Corn silage included at 15% with tylosin.
2. Tylosin × CS, *P*-value for the interaction between corn silage inclusion and tylosin inclusions; tylosin, *P*-value for the main effect of tylosin inclusion; CS, *P*-value for the main effect of corn silage inclusion.
3. Calculated on a carcass-adjusted basis using a common dressing percentage (63%).
4. Marbling Score 300 = Slight, 400 = Small, 500 = Modest, etc.
5. Calculated YG = 2.50 + (6.35 × fat thickness, cm) + (0.2 × KPH, %) + (0.0017 × HCW, kg) – (2.06 × LM area, cm2).
6. Calculated as a percent of total steers; deads removed.

Table 6. Main effect of corn silage inclusion on performance of cattle

Item	*Treatment* [1]		*SEM*	*P-value*
	CS15	*CS45*		
Days on feed	185	213	–	–
Initial BW, kg	294	294	3.45	0.97
Live final BW, kg	584	606	4.68	<0.01
Carcass adjusted performance [2]				
Final BW, kg	585	605	5.18	0.01
DMI, kg/d	9.9	10.5	0.08	<0.01
ADG, kg	1.58	1.46	0.02	<0.01
Carcass characteristics				
HCW, kg	369	381	3.27	0.01
Dressing, %	63.2	63.0	0.14	0.15
LM area, cm^2	89.7	88.4	0.65	0.18
12th rib fat, cm	1.19	1.24	0.03	0.10
Marbling [3]	448	445	5.05	0.69
CYG [4]	2.83	3.04	0.04	<0.01

1. CS, corn silage.
2. Calculated on a carcass-adjusted basis using a common dressing percentage (63%).
3. Marbling Score 300 = Slight, 400 = Small, 500 = Modest, etc.
4. Calculated YG = 2.50 + (6.35 × fat thickness, cm) + (0.2 × KPH, %) + (0.0017 × HCW, kg) − (2.06 × LM area, cm^2).

Additionally, Wilson et al. (2020) reported increased marbling and CYG for cattle fed 47% corn silage, compared to 14%, when fed to a common back fat thickness.

Overall, in this study the incidence of abscessed livers ranged from 12.0% to 34.5%. This level of incidence is similar to that of Meyer et al. (2009) which reported 6.5% to 27.2% abscessed livers when cattle were fed HMC and DRC in a 75:25 ratio with 7.5% alfalfa hay. Similarly, Meyer et al. (2013), fed a 50:50 mixture of HMC and DRC, 25% MDGS and 7% corn silage, and reported abscess prevalence between 8.3 and 42.4. In this study, there was an interaction for abscessed livers, where cattle fed CS15 had the greatest incidence of abscessed livers (34.5%) compared to all other treatments ($P = 0.05$; Table 4). Cattle fed 15% corn silage benefited from the addition of tylosin in the diet by reducing the incidence of abscessed livers from 34.5% to 19.2% (44.3% reduction). This reduction is consistent with reported reduction (40% to 70%) in abscessed livers when cattle were fed tylosin compared to no tylosin (Nagaraja and Chengappa, 1998). However, no differences in incidence of abscessed livers were observed when cattle were fed 45% corn silage with tylosin (12.7%) or without tylosin (12.0%).

There were no interactions for any carcass characteristics ($P \geq 0.20$; Table 4). Muller et al. (2018) observed no differences in LM area, CYG, or quality grade for cattle fed with or without tylosin. However, the authors observed a slight decrease in marbling when cattle were fed tylosin continuously, compared to cattle fed no tylosin, or intermittent dosing. Depenbusch et al. (2008) found increased LM area but reported no difference in marbling score when cattle fed a steam-flaked corn diet were fed tylosin and monensin compared to monensin alone.

As expected, cattle fed 45% corn silage had greater ($P \leq 0.01$) live final BW, carcass-adjusted final BW, and HCW compared to cattle fed 15% corn silage due to the greater days fed to equalize fatness (Table 6). Cattle fed 45% corn silage had greater DMI but decreased ADG compared to cattle fed 15% corn silage ($P \leq 0.01$). Similar results have been reported, where increasing corn silage inclusion in the diet leads to decreased ADG and poorer feed conversions (Hammes et al., 1964; Klosterman et al., 1965; Jesse et al., 1976; Brennan et al., 1987; Rusche et al., 2020). Similarly, all studies used in the pooled analysis also reported a similar performance trend when increasing corn silage inclusion to 45% (Burken et al. 2017a, 2017b; Ovinge et al., 2019; Hilscher et al., 2022). Because previous trials fed cattle for the same number of days, it was critical in this study that cattle were fed to the same fat thickness endpoint.

There was no effect of tylosin for live final BW, carcass-adjusted final BW, and HCW ($P \geq 0.60$; **Table 7**). Additionally, tylosin did not affect DMI or ADG ($P \geq 0.55$). There were no interactions of tylosin for quality grade or calculated yield grade distributions ($P \geq 0.30$; **Table 8**). However, there was a numerical (and likely biological) difference ($P = 0.11$; Table 8) between corn silage and tylosin inclusion for the distribution of abscess severity. In addition to having the greatest incidence of abscessed livers, cattle fed 15% corn silage with no tylosin also had the greatest number livers with severe abscesses, 27.8% with A or A+ liver abscesses.

Table 7. Main effect of tylosin inclusion on performance of cattle

Item	Treatment		SEM	P-value
	−Tylosin	+ Tylosin		
Days on feed	199	199	–	–
Initial BW, kg	294	294	3.45	0.94
Live final BW, kg	593	596	4.68	0.60
Carcass adjusted performance				
Final BW, kg	595	596	5.18	0.82
DMI, kg/d	10.2	10.2	0.08	0.86
ADG 1.51	1.53	0.02	0.54	
Carcass characteristics [1]				
HCW, kg	375	375	3.27	0.84
LM area, cm^2	89.0	88.4	0.65	0.53
12th rib fat, cm	1.22	1.22	0.03	0.69
Marbling [2]	451	443	5.05	0.25
Calculated yield grade [3]	2.92	2.95	0.04	0.54
Dressing, %	63.2	63.0	0.14	0.33

1. Calculated on a carcass-adjusted basis using a common dressing percentage (63%).
2. Marbling Score 300 = Slight, 400 = Small, 500 = Modest, etc.
3. Calculated YG = 2.50 + (6.35 × fat thickness, cm) + (0.2 × KPH, %) + (0.0017 × HCW, kg) − (2.06 × LM area, cm^2).

Severity was lessened (fewer A+) when cattle fed 15% corn silage were fed tylosin. These data suggest that increasing corn silage in the diet had similar effects to adding tylosin to 15% corn silage diets. Additionally, adding tylosin to a 45% corn silage diet had no additional benefits and did not reduce the number of abscessed livers further. Meyer et al. (2009) observed a reduction from 6.9% to 0.0% in A+ abscesses when cattle were fed tylosin at 90 mg/steer daily. Another study observed a decrease in A+ scores from 19% to 4% when cattle were fed tylosin compared to a control with all diets containing 25% MDGS and a 50:50 mix of HMC:DRC (Meyer et al., 2013).

An exploratory analysis was conducted to determine hot carcass distributions relationship with categorical liver abscess score (**Table 9**). Hot carcass weight was significantly reduced (357 kg) when cattle were scored with A+ livers, compared to other severity categories (A−, 370 kg; A, 375 kg) and cattle with no abscesses

Table 8. Carcass quality and liver score distributions of finished steers fed 15% or 45% corn silage, with or without tylosin

Item [2]	*Treatment* [1]			
	−Tylosin		*+ Tylosin*	
	CS15	*CS45*	*TCS15*	*TCS45*
Calculated Yield Grade [3,5]				
1	4.0	1.4	2.7	0.7
2	26.3	20.8	25.8	18.8
3	55.9	55.6	55.0	56.3
4	13.2	21.5	15.9	22.9
>4	0.7	0.7	0.7	1.4
Quality grade [4,6]				
Prime	1.3	2.1	0.0	0.7
Upper 2/3 Choice	24.2	21.4	22.1	21.3
Lower 1/3 Choice	42.7	37.9	35.7	41.1
Select	29.9	37.9	42.2	36.9
<Select	1.9	0.7	0.0	0.0
Liver scores [7]				
0	65.2	87.7	80.5	87.1
A−	7.0	5.8	10.7	8.4
A	10.1	1.9	1.9	2.6
A+	17.7	4.5	6.9	1.9

1. Treatments included CS15, Corn silage included at 15% of diet DM without tylosin; CS45, Corn silage included at 15% of diet DM without tylosin; TCS15, Corn silage included at 15% of diet DM with tylosin; TCS45, Corn silage included at 15% of diet DM with tylosin.
2. All numbers are expressed as percentages of total steers within pen.
3. Calculated YG = 2.50 + (6.35 × fat thickness, cm) + (0.2 × KPH, %) + (0.0017 × HCW, kg) − (2.06 × LM area, cm2).
4. Quality grades based on the marbling score (300 to 399 Select, 400 to 499 low choice, 500 to 699 upper choice, and >700 as prime).
5. Silage concentration: $P = 0.86$, tylosin: $P = 0.31$ Silage concentration × tylosin: $P = 0.27$.
6. Silage concentration: $P < 0.01$, tylosin: $P = 0.37$ Silage concentration × tylosin: $P = 0.98$.
7. Silage concentration: $P < 0.01$, tylosin: $P = 0.21$ Silage concentration × tylosin: $P = 0.11$.

(377 kg). Cattle with A+ abscesses had the greatest standard deviation with the lowest minimum and maximum carcass weights. Because the trial was not able to measure live final BW on individual cattle, these losses in hot carcass weight cannot be directly attributed to either decreased live performance or additional carcass trim at the time of harvest. Additionally, 46% of steers with

Table 9. Hot carcass distributions relationship with categorical liver abscess severity score

Item	*Liver severity score*				*SEM*	*P-value*[1]
	0	*A−*	*A*	*A+*		
Cattle, *n*	501	50	26	49	–	–
Hot carcass weight						
Minimum	277	308	315	273	–	–
Maximum	479	425	420	420	–	–
Standard Deviation	27.1	26.8	23.4	34.1	–	–
Average	377	370	375	357	14.7	<0.01

1. Treatment × Liver severity score: $P = 0.29$.

an A+ liver score had a hot carcass weight of 350 kg or lower (**Figure 1**). However, steers with scores of 0, A, or A− were heavier with only an average of 13% of cattle with hot carcass weights of 350 kg or lower. Only severe abscesses (A+) reduced hot carcass weight in this study. This agrees with Brink et al. (1990) that reported an average 17 kg decrease in hot carcass weight

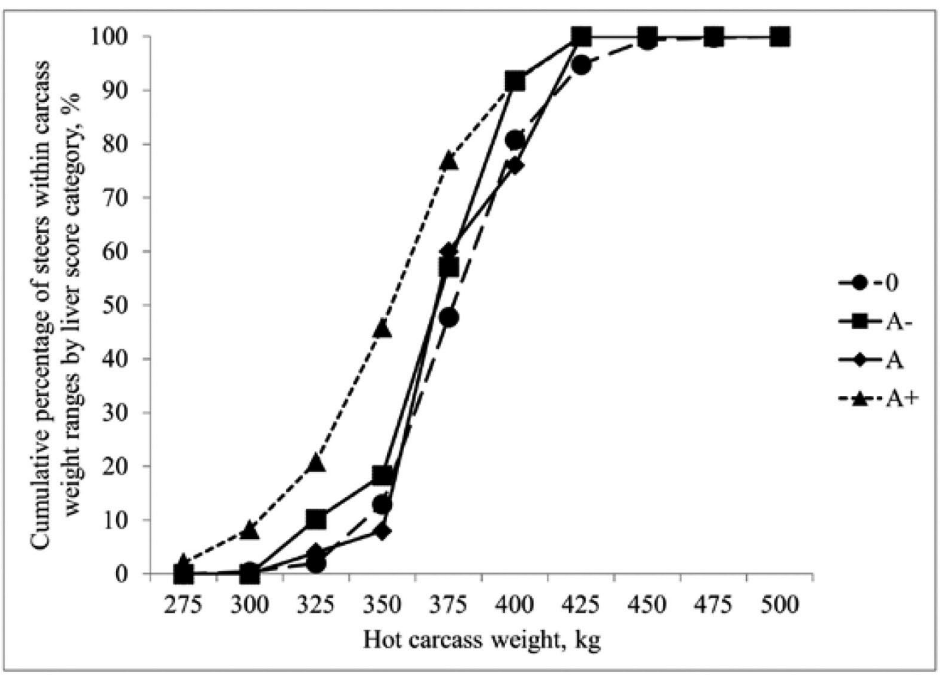

Figure 1. Cumulative percentage of steers within hot carcass weight by liver abscess severity score.

for cattle with A+ liver scores across 12 different studies (in Nebraska) which was attributed to reduced carcass gain and dressing percentage (possibly due to increased carcass trim). Herrick et al. (2018) reported a reduction of hot carcass weight (25.1 kg) from cattle that had A+ liver that were adhered (to the gastrointestinal tract) and possessed an open abscess. Similarly, in an analysis of over 72,000 cattle, Brown and Lawrence (2010) reported reduced hot carcass weights in cattle with liver scores of A+, A+ livers that were adhered, and A+ livers with open abscesses. However, adhesion was not measured in the current study.

It is plausible that by replacing highly digestible starch, from HMC and DRC, with corn silage in this study, volatile fatty concentrations decreased in the rumen which subsequently lowered the potential for acidosis and rumenitis. Studies have proposed the mechanistic effects of rumenitis and acidosis as a major contributor for the development of liver abscesses (Smith, 1944; Jensen et al., 1954; Tan et al., 1994a; b). Fermentation of greater proportions of fiber in corn silage could slow degradation of starch, resulting in an increase in ruminal pH through lower volatile fatty acid production. Additionally, increased fiber also increases mastication which releases more salivary buffer to the rumen (Galyean and Defoor, 2003). It has been observed that the incidence and severity of abscesses decrease as roughage inclusion increases (Harvey et al., 1968; Foster and Wood, 1970; Brent, 1976; Gill et al., 1979; Zinn and Plascencia, 1996). Additionally, increased roughage inclusions promote a more stable rumen environment and decrease intake variation, thus lowering the possibility for acidosis and rumenitis (Nagaraja and Chengappa, 1998).

Cattle that received no tylosin and were fed 15% CS had a high incidence of abscessed livers. This could explain the feed conversion interaction where cattle fed 15% CS with tylosin had improved conversions (2% improvement) compared to cattle fed 15% CS without tylosin. Previous research has suggested that steers burdened with abscesses can suffer performance losses, especially when abscesses are severe (Brink et al., 1990; Davis et al. 2007; Fox et al., 2009; Rezac et al., 2014). In this study, we observed no differences in CYG and quality grade, even for the 15% CS (without tylosin), which had the greatest incidence of severe abscesses.

Davis et al. (2007) reported no difference in marbling between cattle with no liver abscesses and those with abscesses. However, others have reported fewer Choice graded cattle if severe liver abscesses were present and a reduction in marbling, YG, and fat depth (Fox et al., 2009; Brown and Lawrence, 2010).

Corn silage economics

There was a tendency for an interaction ($P = 0.14$; Table 4) between corn silage and tylosin inclusion for returns ($/ steer). Projected profitability was least ($−9.57/steer) for feeding 15% corn silage without tylosin compared to $13.43, $9.61, and $7.39 for CS45, TCS15, and TCS45, respectively. Cattle fed 15% corn silage without tylosin suffered performance losses, with poorer feed conversions, compared to cattle fed 15% corn silage with tylosin. The greatest returns were observed when cattle were fed 45% corn silage without tylosin due to increased final and carcass weights while also decreasing the overall cost of the ration. Even though cattle were fed longer and had poorer efficiencies when fed 45% corn silage, the reduced feed costs and increased BW led to similar or greater returns compared to just adding tylosin to 15% corn silage diets.

Feed costs heavily influence profitability and corn silage has been found to be economical in times of high corn prices (Goodrich et al., 1974; Gill et al., 1976; DiCostanzo et al., 1998). Differences in returns ($/steer), based on corn price, were evaluated at the varying inclusions of corn silage (**Table 10**). As corn price (and corn silage price) increased there was a greater difference in the returns ($/steer) when cattle were fed 45% corn silage. For example, at $3.00 corn, cattle fed 45% corn silage returned an additional $11.87 per steer compared to cattle fed 15% corn silage. Furthermore, when corn was $5.00, returns were even greater ($40.64/steer) for cattle fed 45% corn silage compared to 15% corn silage. Overall, increasing corn price led to an increase in returns as $/steer when cattle were fed more corn silage because of the difference in ration price. These data suggest, as corn becomes more expensive, it becomes more economical to feed corn silage at greater inclusions.

Table 10. Estimated returns ($/steer) at varying corn prices for three inclusions of corn silage fed to feedlot cattle [1]

Dry corn price [3], *$/25.4 kg*	*Feeder calf price* [4], *$/45.4 kg*	*Treatment* [2]	
		CS15 (*Net return, $*)	*CS45* (*Net return, $*)
3.00	1.7743	0.05	11.92
4.00	1.6435	0.02	26.37
5.00	1.5125	0.04	40.68

1. Returns calculated as the difference in gross inputs and revenues. Values represent profit in dollars per head ($/steer). Inputs: Total feed costs including processing and shrink. Cattle Interest = [(days on feed/365) × (feeder price −$200) × 0.75]. Feed Interest = [Total feed costs/2) × 0.75 × (days on feed/365)]. Yardage = $ 0.50/steer/d. Processing = $20/steer. Revenue: Final body weights using a 63% common dressing percent to calculate live final weight and 5-year average live fat price for Nebraska ($1.25/45.4 kg).
2. CS, corn silage.
3. Corn silage prices floated with the price of corn utilizing a September corn price comparison ($ −0.20/25.4 kg) compared to $3, $4, and $5 dry corn. The corn silage prices were $35.24 (per metric tons DM), $38.70, $42.25, respectively.
4. Initial purchase price was set to break even for 15% corn silage.

Cattle fed 45% corn silage had poorer ADG and G:F but greater final BW when finished to a common back fat thickness compared with cattle fed 15% corn silage. Feeding tylosin in diets containing 92.5% concentrate led to a decrease in incidence of abscessed livers. However, feeding corn silage at 45% (77.5% concentrate) also decreased the incidence of abscessed livers with or without the inclusion of tylosin with similar or improved performance compared to cattle fed 15% corn silage. Furthermore, feeding 45% corn silage also shifted the severity distribution with cattle having fewer A+ liver scores compared to cattle fed 15% corn silage. Overall, feeding corn silage at 45% to finishing cattle was as effective as feeding tylosin to reduce liver abscesses and is an economical way to finish cattle.

It should be noted that feeding corn silage at 45% is inherently part of a system wide approach to feeding cattle. This would include a tailored step-up (like the one used in this study) that does not step cattle all the way up on a higher concentrate diet. Additionally, because of the diluted nature of the diet, reducing energy will inevitably increase the number of days on feed required to reach a similar finishing point to conventional cattle. Additionally, procuring the amount of silage needed to feed cattle may become increasingly difficult for large scale operations or in times of drought when corn production is limited. It should also be noted that pen size, number of cattle, and bunk space all play a role in the competitive feeding nature of cattle, potentially leading to other considerations when feeding higher concentrations of corn silage.

If more silage is fed (up to 45%), then cattle need to be fed longer to achieve a similar fat endpoint, so grade is not hindered. Based on the current study, this is approximately 28 d if increasing dietary silage inclusion from 15% to 45%. By feeding 28 d longer, sellable carcass weight increases (and live weight). So, despite more yardage and feed inputs, the diet cost was lower, and the slightly heavier cattle (12 kg more carcass weight) allow for the operation to be more profitable. The estimated increased profit is approximately $10.50 per head. Based on the current data, feeders that own their own farm acres to produce corn silage can avoid or reduce the use of antibiotics, for sole purpose of reducing liver abscesses, if they feed 45% silage in diets with DGS. That management change could also enhance their profitability of the farming/feeding operation.

Acknowledgments A contribution of the University of Nebraska Agricultural Research Division supported in part by funds provided by the Hatch Act. Funding provided by the Iowa Beef Industry Council through the Beef Checkoff.

Conflict of Interest The authors declare no conflicts of interest.

Literature Cited

AOAC. 1999. *Official methods of analysis*. 16th edn. Washington: Association of Official Analytical Chemists.

Brennan, R. W., M. P. Hoffman, F. C. Parrish, F. Epplin, S. Bhide, and E. O. Heady. 1987. Effects of differing ratios of corn silage and corn grain on feedlot performance, carcass characteristics, and projected economic returns. *J. Anim. Sci.* 64:23–31. https://doi.org/10.2527/jas1987.64123x

Brent, B. E. 1976. Relationship of acidosis to other feedlot ailments. *J. Anim. Sci.* 43:930–935. https://doi.org/10.2527/jas1976.434930x

Brink, D. R., S. R. Lowry, R. A. Stock, and J. C. Parrott. 1990. Severity of liver abscesses and efficiency of feed utilization of feedlot cattle. *J. Anim. Sci.* 68:1201–1207. https://doi.org/10.2527/1990.6851201x

Brown, T. R., and T. E. Lawrence. 2010. Association of liver abnormalities with carcass grading performance and value. *J. Anim. Sci.* 88:4037–4043. https://doi.org/10.2527/jas.2010-3219

Brown, H., R. F. Bing, H. P. Grueter, J. W. McAskill, C. O. Cooley, and R. P. Rathmacher. 1975. Tylosin and chlortetracycline for the prevention of liver abscesses, improved weight gains and feed efficiency in feedlot cattle. *J. Anim. Sci.* 40:207–213. https://doi.org/10.2527/jas1975.402207x

Burken, D. B., B. L. Nuttelman, J. L. Gramkow, M. J. Jolly-Briethaupt, J. L. Gramkow, S. E. Gardine, T. J. Klopfenstein, J. C. MacDonald, and G. E. Erickson. 2017a. Digestibility and performance of steers fed varying inclusions of corn silage and modified distillers grains with solubles to partially replace corn in finishing diets. *Transl. Anim. Sci.* 1:382–396. https://doi.org/10.2527/tas2017.0046

Burken, D. B., B. L. Nuttelman, J. L. Gramkow, A. L. McGee, K. M. Sudbeck, S. E. Gardine, T. C. Hoegemeyer, T. J. Klopfenstein, and G. E. Erickson. 2017b. Effects of agronomic factors on yield and quality of whole corn plants and the impact of feeding high concentrations of corn silage in diets containing distillers grains to finishing cattle. *Transl. Anim. Sci.* 1:367–381. https://doi.org/10.2527/tas2017.0045

Davis, M. S., W. C. Koers, K. J. Vander Pol, and O. A. Turgeon. 2007. Liver abscess score and carcass characteristics of feedlot cattle. *J. Anim. Sci.* 85:126–127.

Depenbusch, B. E., J. S. Drouillard, E. R. Loe, J. J. Higgins, M. E. Corrigan, and M. J. Quinn. 2008. Efficacy of monensin and tylosin in finishing diets based on steam-flaked corn with and without corn wet distillers grains with solubles. *J. Anim. Sci.* 86:2270–2276. https://doi.org/10.2527/jas.2007-0017

DiCostanzo, A., C. M. Zehnder, and H. Chester-Jones. 1998. Economics of feeding corn silage in feedlot diets. *Univ. of MN, St. Paul, MN.* B-456:28–37.

Edwards, W., and D. Loy 2017. *Silage pricer-corn silage. Version 1.4_82017*. Iowa State Extension. https://www.extension.iastate.edu/agdm/crops/html/a1-65.html

Foster, L., and W. R. Wood. 1970. *Liver losses in finishing cattle*. Lincoln: Nebraska Beef Cattle Report University of Nebraska; p. 2–4.

Fox, J. T., D. U. Thomson, N. N. Lindberg, and K. Barling. 2009. A comparison of two vaccines to reduce liver abscesses in natural-fed beef cattle. *Bov. Pract*. 43:168–174. https://doi.org/10.21423/bovine-vol43no2p168-174

Galyean, M. L., and P. J. Defoor. 2003. Effects of roughage source and level on intake by feedlot cattle. *J. Anim. Sci*. 81:E8–E16. https://doi.org/10.2527/2003.8114_suppl_2E8x

Gill, D. R., J. R. Martin, and R. Lake. 1976. High, medium, and low corn silage diets with and without monensin for feedlot steers. *J. Anim. Sci*. 43:363–368. https://doi.org/10.2527/jas1976.432363x

Gill, D. R., F. N. Owens, R. W. Fent, and R. K. Fulton. 1979. Thiopeptin and roughage level for feedlot steers. *J. Anim. Sci*. 49:1145–1150. https://doi.org/10.2527/jas1979.4951145x

Goodrich, R. D., D. W. Crawford, M. L. Thonney, and J. C. Meiske. 1974. Influence of corn silage level on the performance and economic returns of steer calves. *MN Cattle Feeder Rep. Univ. of MN, St. Paul, MN*. B-195:14–19

Hammes, R. C. Jr, J. P. Fontenot, H. T. Bryant, R. E. Blaser, and R. W. Engle. 1964. Value of high silage rations for fattening beef cattle. *J. Anim. Sci*. 23:795–801. https://doi.org/10.2527/jas1964.233795x

Harner, J. P., and J. P. Murphy. 2021. Planning cattle feedlots. Kansas State University, Manhattan Extension pub MF-2316rev. https://bookstore.ksre.ksu.edu/pubs/MF2316.pdf

Harvey, R. W., M. B. Wise, T. N. Blumer, and E. R. Barrick. 1968. Influence of added roughage and chlortetracycline to all-concentrate rations for fattening steers. *J. Anim. Sci*. 27:1438–1444. https://doi.org/10.2527/jas1968.2751438x

He, Z. X., M. L. He, N. D. Walker, T. A. McAllister, and W. Z. Yang. 2014. Using a fibrolytic enzyme in barley-based diets containing wheat dried-distillers grains with solubles: Ruminal fermentation, digestibility, and growth performance of feedlot steers. *J. Anim. Sci*. 92:3978–3987. https://doi.org/10.2527/jas.2014-7707

Herrick, R., C. Rogers, T. Jones, T. McEvers, T. Brown, C. Maxwell, and T. Lawrence. 2018. 481 Association of liver abscess presence and severity with trim loss, harvest yield, carcass grading performance, lung lesions, and value of fed Holsteins. *J. Anim. Sci*. 96:269–269. https://doi.org/10.1093/jas/sky404.589

Hilscher, F. H., D. B. Burken, C. J. Bittner, J. L. Gramkow, R. G. Bondurant, M. L. Jolly-Breithaupt, A. K. Watson, J. C. MacDonald, T. J. Klopfenstein, and G. E. Erickson. 2019. Impact of corn silage moisture at harvest on performance of growing steers with supplemental rumen undegradable protein, finishing steer performance, and nutrient digestibility by lambs. *Transl. Anim. Sci.* 3:761–774. https://doi.org/10.1093/tas/txz011

Hilscher, F. H., C. J. Bittner, J. L. Gramkow, M. L. Jolly-Breithaupt, M. M. Norman, H. C. Wilson, A. K. Watson, J. C. MacDonald, J. N. Anderson, and G. E. Erickson. 2022. The effect of corn silage hybrid and inclusion on performance of finishing steers and silage hybrid effects on digestibility and performance of growing steers. *Transl. Anim. Sci.* 6:1–10 https://doi.org/10.1093/tas/txac147

Jensen, R. H., M. Deane, L. J. Cooper, V. A. Miller, and W. R. Graham. 1954. The rumenitis-liver abscess complex in beef cattle. *Am. J. Vet. Res.* 15:202–216.

Jesse, G. W., G. B. Thompson, J. L. Clark, K. G. Weimer, and D. P. Hutcheson. 1976. Effects of various ratios of corn and corn silage and slaughter weight on the performance of steers individually fed. *J. Anim. Sci.* 43:1049–1057. https://doi.org/10.2527/jas1976.4351049x

Klosterman, E. W., P. G. Althouse, and V. R. Cahill. 1965. Effect of corn silage or ground ear corn full fed at various stages of growth and fattening upon carcass composition of beef cattle. *J. Anim. Sci.* 24:454–458. https://doi.org/10.2527/jas1965.242454x

Koelsch, R. 2013. *Feed Nutrient Management Planning Economics (BNFMP$).* Lincoln: University of Nebraska–Lincoln Extension. https://water.unl.edu/article/animal-manure-management/software

Meyer, N. F., G. E. Erickson, T. J. Klopfenstein, M. A. Greenquist, M. K. Luebbe, P. Williams, and M. A. Engstrom. 2009. Effect of essential oils, tylosin, and monensin on finishing steer performance, carcass characteristics, liver abscesses, ruminal fermentation, and digestibility. *J. Anim. Sci.* 87:2346–2354. https://doi.org/10.2527/jas.2008-1493

Meyer, N. F., G. E. Erickson, T. J. Klopfenstein, J. R. Benton, M. K. Luebbe, and S. B. Laudert. 2013. Effects of monensin and tylosin in finishing diets containing corn wet distillers grains with solubles with differing corn processing methods. *J. Anim. Sci.* 91:2219– 2228. https://doi.org/10.2527/jas.2011-4168

Muller, H. C., C. L. Van Bibber-Krueger, O. J. Ogunrinu, R. G. Amachawadi, H. M. Scott, and J. S. Drouillard. 2018. Effects of intermittent feeding of tylosin phosphate during the finishing period on feedlot performance, carcass characteristics, antimicrobial resistance, and incidence and severity of liver abscesses in steers. *J. Anim. Sci.* 96:2877–2885. https://doi.org/10.1093/jas/sky166

Nagaraja, T. G., and M. M. Chengappa. 1998. Liver abscesses in feedlot cattle: a review. *J. Anim. Sci.* 76:287–298. https://doi.org/10.2527/1998.761287x

Ovinge, L. A., F. H. Hilscher, B. M. Boyd, J. N. Anderson, G. E. Erickson. 2019. *Effects of varying silage inclusion of brown midrib corn silage on finishing and economic performance of steers. Nebraska Beef Cattle Report. 1027*. http://digitalcommons.unl.edu/animalscinbcr/1027

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: a review. *J. Anim. Sci.* 76:275–286. https://doi.org/10.2527/1998.761275x

Potter, E. L., M. I. Wray, R. D. Muller, H. P. Grueter, J. McAskill, and D. C. Young. 1985. Effect of monensin and tylosin on average daily gain, feed efficiency and liver abscess incidence in feedlot cattle. *J. Anim. Sci.* 61: 1058–1065. https://doi.org/10.2527/jas1985.6151058x

Rezac, D. J., D. U. Thomson, S. J. Bartle, J. B. Osterstock, F. L. Prouty, and C. D. Reinhardt. 2014. Prevalence, severity, and relationships of lung lesions, liver abnormalities, and rumen health scores measured at slaughter in beef cattle. *J. Anim. Sci.* 92:2595–2602. https://doi.org/10.2527/jas.2013-7222

Rusche, W. C., J. A. Walker, and Z. K. Smith. 2020. Effect of inclusion rate of silage with or without alpha-amylase trait on finishing steer growth performance, carcass characteristics, and agronomic efficiency measures. *Transl. Anim. Sci.* 4:942–949. https://doi.org/10.1093/tas/txaa056

Smith, H. A. 1944. Ulcerative lesions of the bovine rumen and their possible relation to hepatic abscesses. *Am. J. Vet. Res.* 5:234–242.

Tan, Z. L., T. G. Nagaraja, and M. M. Chengappa. 1994a. Biochemical and biological characterization of ruminal Fusobacterium necrophorum. *FEMS Microbiol. Lett.* 120:81–86. https://doi.org/10.1111/j.1574-6968.1994.tb07011.x

Tan, Z. L., T. G. Nagaraja, and M. M. Chengappa. 1994b. Selective enumeration of Fusobacterium necrophorum from the bovine rumen. *Appl. Environ. Microbiol.* 60:1387–1389. https://doi.org/10.1128/aem.60.4.1387-1389.1994

United States Department of Agriculture. 2021. *National Agricultural Statistics Service. Livestock Slaughter*. ISSN: 0499-0544 http://www.nass.usda.gov/Publications/Todays_Reports/reports/lstk0921.pdf

Wilson, H. C., F. H. Hilscher, Z. E. Carlson, B. M. Boyd, A. K. Watson, J. C. MacDonald, and G. E. Erickson. 2020. Impact of a fumaric acid and palm oil additive on beef cattle performance and carcass characteristics in diets containing increasing concentrations of corn silage. *Transl. Anim. Sci.* 2020:910–921. https://doi.org/10.1093/tas/txaa043

Zinn, R. A., and A. Plascencia. 1996. Effects of forage level on the comparative feeding value of supplemental fat in growing/ finishing diets for feedlot cattle. *J. Anim. Sci.* 74:1194–1201. https://doi.org/10.2527/1996.7461194x