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2021 Nebraska Beef Cattle Report

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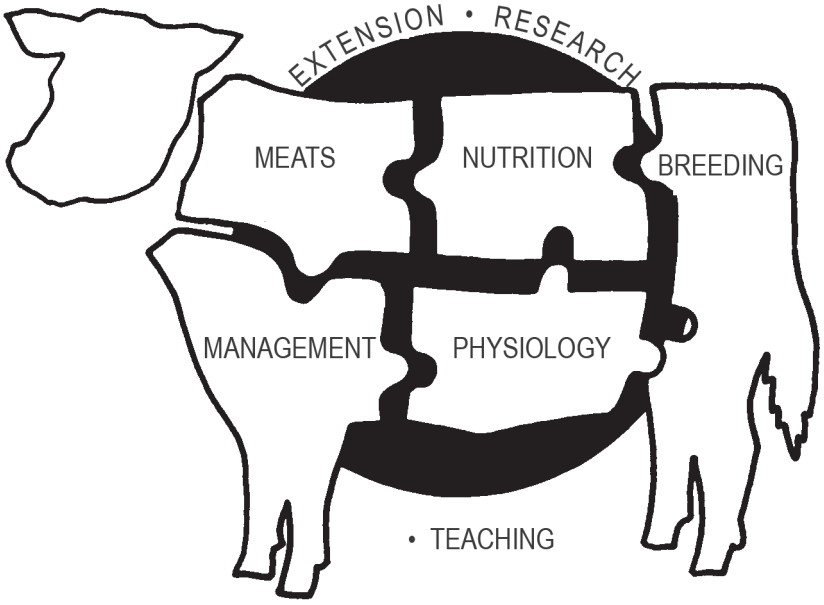

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2021 Beef Cattle Report

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Summary with Implications

A 4-yr study utilizing heifers from March and May calving herds collected serum samples prior to breeding to determine puberty status. Serum samples were used for Metabolomics analysis to investigate differences related to circulating serum metabolites in pubertal and non-pubertal heifers. Metabolomics, which is a shotgun approach analysis of a large number of small metabolites, is an emerging technology that can provide a more robust analysis of metabolism. No differences were observed in heifer ADG, pregnancy rate, or the percentage that calved within the first 21 d between heifers classified as pubertal and non-pubertal at the start of the breeding season. Using metabolomic analysis, metabolite differences associated with energy metabolism and steroid production between pubertal and non-pubertal groups were identified. Results from this study suggest that there is potential to develop a method that identifies efficient, productive females early in the development period and reduce costs for producers.

Introduction

The early part of the life of a heifer is heavily influenced by their metabolism which experiences drastic shifts throughout this critical growth period to ensure proper growth and reproductive competence in her attainment of puberty prior to breeding. These changes affect protein, carbohydrate, and lipid metabolism through altered nutrient requirements, not only during the heifer development stage but subsequent lifetime productivity as a replacement female in the beef herd. Exponential early growth increases metabolic demand and allows for adaptive changes to occur in those pathways associated with metabolism. Metabolomic analysis provides an overview of those metabolic pathways and associated phenotype. This method allows researchers to look at serum metabolite profiles in a complete systems-wide metabolism and biology approach. . Combining biological mechanism with metabolomics holds the potential to identify efficient, productive females to be used as replacements reducing producer costs. Therefore, the hypothesis of this study that the metabolite profiles of serum collected from heifers prior to their respected breeding season will be different among pubertal and non-pubertal groups.

Table 1. Forage quality prior to the breeding season for March and May calving herds over a four-year period[1]

Item, %DM	2011[1]	2012	2013	2014
March[2]				
CP	14.0	10.1	19.3	14.1
TDN	64.3	61.5	79.7	61.6
May[3]				
CP	11.1	10.6	14.7	10.1
TDN	61.2	59.6	71.0	59.0

[1]Nutritional composition of range was collected from esophageal fistulated cows in each year

[2]March= heifers born from the March-calving herd

[3]May= heifers born from the May-calving herd

Procedure

A 4-yr study conducted at the Gudmundsen Sandhills Laboratory, Whitman, Nebraska, developed replacement heifers from 2 calving seasons. March-born (n = 225) and May-born (n = 258), crossbred (5/8 Red Angus, 3/8 Continental) heifers were maintained with their respective calving herds. Nutrient composition (Ward Labs, Kearney, NE) for the pasture is presented in Table 1, noting the quality of the pasture for the breeding season. Puberty status was determined prior to each breeding season by collecting 2 blood samples via coccygeal venipuncture 10 d apart (May for March-born heifers and early July for May-born heifers). Heifers with serum progesterone concentrations greater than 1 ng/mL at either collection were considered pubertal, anything below 1 ng/mL at either time point was considered non-pubertal. Blood samples were placed on ice following collection and centrifuged at 2,500 × *g* for 20 min at 4°C. Following serum removal, samples were frozen at −20°C pending analysis. At breeding, heifers were synchronized with a single 5 mL i.m. injection of $PGF_{2\alpha}$ (Lutalyse, Zoetis, Parsippany, NJ) 5 d after bull placement (1:20 bull-heifer ratio) and bulls successfully completed a breeding soundness exam before a 45 d breeding season. Heifer pregnancy diagnosis was conducted via transrectal ultrasonography 40 d following bull removal. Metabolite data were normalized by sample volume and then a model was used to identify metabolites related to branched chain-amino acids metabolism, lipid metabolism, carbohydrate metabolism, and steroidogenic biosynthesis to be different in pubertal and non-pubertal heifers. Performance data were analyzed using the PROC MIXED and GLIMMIX procedure of SAS. A mixed model ANOVA accounted for correlations within puberty class and puberty class within each calving season.

Table 2. Growth and reproductive performance between pubertal and non-pubertal heifers

	Treatments			
Items	Non-Pubertal	Pubertal	SE	*P*-value
March[1]				
ADG[2], lbs	2.1	1.8	0.4	0.42
Pregnancy Rate, %	83.5	91.3	5.5	0.15
First 21 d[3], %	72.3	77.7	7.6	0.47
Number of calves[4]	2.22	2.31	0.22	0.68
May[5]				
ADG, lbs	1.0	1.1	0.1	0.10
Pregnancy Rate, %	62.9	72.7	7.1	0.17
First 21 d, %	53.1	52.4	2.0	0.78
Number of calves	1.89	2.34	0.23	0.06

[1]March= heifers born from the March-calving herd

[2]ADG= average daily gain of BW during the breeding season

[3]First 21 d= calving within the first 21 d of the calving season indicative of conceiving within the first 21 d of the breeding season

[4]Number of calf crops for each heifer

[5] May= heifers born from the May-calving herd

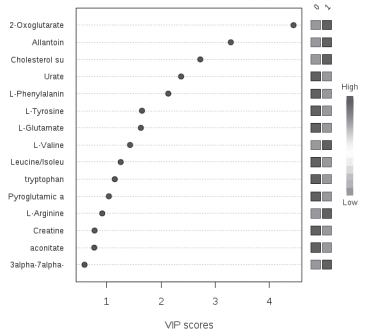

Figure 1. VIP scores of March-born heifers (0 = non-pubertal heifers; 1= pubertal heifers). VIP scores measure the importance of the variable between pre-breeding pubertal status, the greater the VIP number the greater the importance. Color-coded boxes (red = high concentration; green = low concentration) for non-pubertal (0) and pubertal (1) heifers signify the concentration difference of the measure variable.

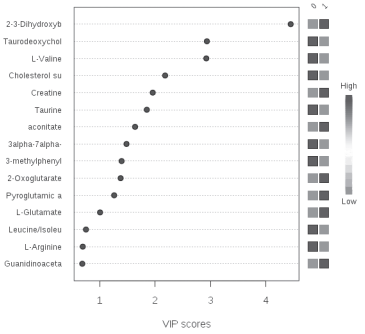

Figure 2. VIP scores of May-born heifers (0 = non-pubertal heifers; 1= pubertal heifers). VIP scores measure the importance of the variable between pre-breeding pubertal status, the greater the VIP number the greater the importance. Color-coded boxes (red = high concentration; green = low concentration) for non-pubertal (0) and pubertal (1) heifers signify the concentration difference of the measure variable.

Models included the effect of treatment, cow age, calving season, and calf sex for all appropriate data. Data are presented as LSMEANS and *P-v*alues ≤ 0.05 were considered significant and tendencies were considered at a $P > 0.05$ and $P \leq 0.10$. Longitudinal data of the serum metabolome were analyzed in MetaboAnalyst 3.0 (Xia and Wishart, 2011). The functions used were principal component analysis (PCA) to depict variation in the data distributed across samples and *t*-test. With distinction of important metabolites classified between the groups using the variable importance projection (VIP) method.

Results

Heifer average daily gain during the breeding season was not different ($P > 0.10$; Table 2) between puberty groups. At the start of breeding, 58% and 66% were classified as pubertal in March- and May-heifers, respectively. However, heifer reproductive performance was not different ($P \geq 0.10$) between puberty classifications prior to the breeding season for final pregnancy rate and the percentage that calved within the first 21 d. These results suggest the later maturing non-pubertal heifers prior to breeding were able to obtain a later puberty with no negative impacts on timing and ability to conceive. Heifer average daily gain was not different between pubertal and non-pubertal groups suggesting that heifers had similar nutrient intake thus body weight did not impact puberty attainment, which challenges current understanding of body weight attainment at time of breeding.

A total of 64 metabolites were identified from pubertal and non-pubertal heifers within each calving season. March-born pubertal heifers had increased ($P \leq 0.01$) concentrations of 2-oxoglutarate compared to non-pubertal heifers (Fig 1). A key molecule in the Krebs cycle (TCA cycle) is 2-oxoglutarate or α-ketoglutarate (AKG). The influence of AKG on the intracellular mechanisms may lead to a greater impact on the neuroendocrine systems, which drives attainment of puberty in heifers. Pubertal heifers with increased blood concentrations of AKG may have increased TCA cycle enzymatic activity, which may increase energy metabolism while stimulating the neuroendocrine activity associated with puberty attainment.

Non-pubertal March heifers had greater ($P < 0.01$) concentrations of creatine and aconitase (Fig 1), which play a role in muscle metabolism, protein breakdown, and catalyzes enzyme reactions for citrate in the TCA cycle. If not used to create energy, creatine is then metabolized to creatinine. The changes of creatine concentration from pre-and post-puberty could be influenced by fluctuation of estrogens during puberty attainment. Aconitate or better known as it's active form aconitase serves as an iron-dependent enzyme catalyst for citrate and iso citrate in the TCA cycle. Therefore, non-pubertal March-heifers with increased aconitase may indicate inefficiencies in the energy metabolism.

May-born pubertal heifers had increased ($P \leq 0.01$) concentrations of 2,3-dihydroxybenzoate (Fig 2) and decreased ($P \leq 0.01$) concentrations of taurodeoxycholate and cholesterol sulfate

(Fig 2) compared to non-pubertal counterparts. This suggests that pubertal heifers with elevated 2,3-dihydroxybenzoate are undergoing bone maturation sooner than the non-pubertal heifers. Taurodeoxycholate acts as a bile salt synthesized in the liver to facilitate excretion, absorption, and transport of fats and sterols in the intestine and liver. Bile salts are key components in regulating enzymes involved in cholesterol homeostasis. This would suggest cholesterol sulfate functions as a regulator of cholesterol side chain cleavage activity and steroid synthesis. Increased cholesterol sulfate concentrations in non-pubertal heifers may suggest decreased steroidogenesis, which may delay the onset of puberty.

Conclusions

In this study, puberty attainment prior to breeding season was characterized by differences in metabolic profiles related to protein, lipid, and carbohydrate metabolism along with steroidogenic biosynthesis. Even though no differences were observed in heifer growth and reproductive performance, this untargeted metabolic analysis identified markers associated with energy efficiency in pubertal and non-pubertal heifers. Overall, this furthers the understanding of the metabolic impact on reproductive efficiency in range beef heifers, which possibly may be utilized as a replacement heifer selection tool for producers.

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Milk Production Impacts on Cow Reproductive and Calf Growth Performance

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Summary with Implications

Cattle records were collected and analyzed over an 18-year period to evaluate the impact of milk production on reproductive performance and pre- and post-weaning calf performance of a March-calving herd in the Nebraska Sandhills. Milk production positively increased with increasing cow body weight and age. Pregnancy rates and subsequent calving date were not impacted by milk production. Calf pre-weaning average daily gain and adjusted 205-d weaning weight were increased by 0.7 lb/d and 13.4 lb for every 1 lb increase in milk production. These increases in pre-weaning performance followed calves through the feedlot resulting in a tendency for heavier final live calf body weight and hot carcass weight. However, carcass quality characteristics were not influenced by dam milk production. This study implies that increasing milk production resulted in greater pre-weaning performance to produce calves with heavier weaning weights. Calves from increased milking dams maintained their greater weaning body weight throughout the finishing period to produce heavier carcasses.

Introduction

As cow-calf producers focus on greater weaning weights, selection for increased production parameters including milk production and weaning weight have become prevalent. Historically, milk production has been positively associated with calf body weight with an increase in calf weaning weight with increasing dam milk production. However, increased cow-calf production may not be captured due to environmental conditions and resource availability. This can be observed in a spring calving Sandhills herd due to the lower forage quality during peak lactation, a time of increasing nutrient requirements. Modeling the nutrient requirements for 2- and 4-year old cows with varying levels of milk production resulted in an energy deficiency in both age groups at peak lactation for March-calving cows (*2020 Nebraska Beef Cattle Report*, pp. 5–7). If nutrients are not met at this time of high demand, reproductive performance can be negatively impacted by delaying return to estrus. The objective of this study was to determine the impact milk production has on subsequent cow reproductive performance and calf performance throughout the pre- and post-weaning phases.

Table 1. Demographics of cows utilized for data collection from 2000–2018 for average lactation period and pre-breeding season (June)

	Lactation Period Average[1]			Pre-breeding Average[2]		
Measurement	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Cow Age, yr	2	11	3.56	--	--	--
Cow BW, lb	623	1885	1002	579	1804	936
Cow BCS	4.00	7.00	5.29	4.00	7.00	5.20
Milk Yield, lb/d	3.20	27.34	12.78	0.79	31.6	15.0
Julian Calving Date, d	53	123	79.5	--	--	--
Calf Birth BW, lb	50.4	116	77.5	--	--	--

[1]Lactation period average accounts for June–November.

[2]Pre-breeding average is based on data collected in June.

Procedure

Data was collected between the years 2000–2018 from the March calving herd at the University of Nebraska Gudmundsen Sandhills Laboratory (Whitman, NE). Cows (n = 348; n = ~ 20/yr) utilized were Husker Reds (5/8 Red Angus and 3/8 Simmental) and were 2 to 11 years of age (Table 1). In year 2000 and 2015 to 2018, cows were assigned to one of two grazing treatments: meadow or range. From years 2001 to 2014, all cows were grazed on upland range.

Cow body weight (BW) and body condition score (BCS) were taken in June, July, September, November, and January. Weigh-suckle-weigh was used to estimate milk production in June, July, September, and November by separating calves from cows by 1000 h and allowed to suckle at 1700 h before being separated again. Calf BW were taken at 0700 h the following morning at which time cows and calves were paired up, allowing calves to suckle. Upon completion of suckling period (not exceeding 30 minutes), calves were weighed again. Difference in calf BW was calculated and used to extrapolate for milk production over 24 hr based on hourly production. Detection of pregnancy was determined via ultrasound each September. Calf BW was recorded at birth (March/April), June, July, September, and November. Weaning weights were adjusted to a 205-d age constant BW. A subset of steers (total n = 87; Table 2) were held in a drylot on ad libitum hay for 2 weeks postweaning and then shipped to West Central Research and Extension Center (North Platte, NE) and entered into the feedlot. Calves were stepped up over a 21-d period to a diet containing 48% dry rolled corn, 40% wet corn gluten feed, 7% ground grass hay, and 5% supplement on a dry matter basis. Steers were implanted with Synovex Choice upon entry to the feedlot and reimplanted with Synovex Plus 105 d later. Calves were

Table 2. Number of steers entering the feedlot at West Central Research and Extension Center (North Platte, NE)

Year	Number of Calves
2009	9
2011	10
2012	10
2015	21
2016	21
2017	16

slaughtered upon visual estimation of ½-inch backfat (BF) and carcass quality data was collected.

Data were averaged throughout the lactation period and used as variables in production models. Cow age and cow BW were included in the model as covariates due to their significant impact on milk production. Year and cow served as random effects in all models. Significance level was set at $\alpha \leq 0.05$.

Results

Average milk production throughout the lactation period was positively influenced by cow BW and cow age ($P < 0.001$; Table 3). Every additional 100 lb of cow BW resulted in a 2.0 lb increase in daily milk production. Cow age also positively impacted milk production with an increase of 0.20 lbs per year of age. These increases from cow BW and cow age could be due to the overall average of the herd being young, suggesting that many cows had yet to reach maturity when data was collected. Studies have shown increasing milk production up to 8 years of age in cows, which would agree with the average increase in age observed in these cows averaging 3.5 yrs of age. However, milk production did not impact cow pregnancy rate nor subsequent calving date ($P \geq 0.43$; Table 4).

Increases in adjusted 205-d calf weaning BW and pre-weaning ADG were observed due to milk production. Pre-weaning ADG increased ($P < 0.01$; Table 5) by 0.07 lb/d for every pound increase of milk production. This increase in pre-weaning ADG resulted in greater adjusted 205-d calf weaning BW ($P < 0.01$) by 13.4 lb of calf BW for every pound increase in milk production.

Dam milk production had no impact ($P \geq 0.18$; Table 6) on backfat thickness or marbling score in progeny. Additionally, quality grade and ribeye area were not influenced ($P \geq 0.49$) by increasing dam milk production. However, yield grade tended ($P = 0.06$) to increase with increasing dam milk production. Final live calf BW after the finishing phase increased ($P < 0.01$; Table 6) by 18.9 lb for every pound increase of milk production. In addition, HCW was increased ($P < 0.01$) by an additional 14.6 lb for every

Table 3. Regression coefficient estimates used to determine the increase of cow demographics on milk yield (lb)

Measurement	Estimate[1]	SEM	*P*-value
Average Milk Yield			
Cow Age, yr	0.02	0.07	< 0.001
Average Cow BW, 100 lb	2.00	0.37	< 0.001
Pre-breeding Milk Yield			
Julian Date of Birth, d	0.02	0.01	0.018
Cow Age, yr	0.29	0.10	0.003
Average Cow BW, 100 lb	2.33	0.51	< 0.001

[1]Estimates provide the increase or decrease response in the measured variable for every additional increase in fixed effect.

Table 4. Impact of milk production on cow reproductive performance

	Estimate	SEM	*P*-value
Pregnancy Rate, %	0.003	0.35	0.99
Subsequent calving date, d	0.38	0.48	0.43

[1]Estimates provide the increase or decrease response in the measured variable for every additional 1 lb increase in milk production.

Table 5. Regression coefficients used to estimate the increase on pre-weaning calf performance per lb increase of milk production

Measurement	Estimate[1]	SEM	*P*-value
Pre-breeding calf BW, lb	3.50	0.75	< 0.001
Pre-weaning ADG, lb/d	0.07	0.009	< 0.001
Adj. 205-d calf BW, lb	13.4	1.48	< 0.001

[1]Estimates provide the increase or decrease response in the measured variable for every additional 1 lb increase in milk production.

Table 6. Regression coefficients used to estimate the increase on post-weaning calf performance and carcass characteristics per lb increase of milk production

Measurement	Estimate[1]	SEM	*P*-value
Feedlot Live Performance			
Feedlot ADG, lb/d	0.04	0.04	0.96
Final Live Calf BW, lb	23.3	7.73	< 0.01
Carcass Characteristics			
Hot Carcass Weight, lb	14.6	4.88	< 0.01
Quality Grade[2]	-0.017	0.025	0.49
Yield Grade	0.105	0.055	0.06
Ribeye Area, in	0.011	0.010	0.91
Marbling Score	2.37	5.98	0.69
Backfat, in	0.016	0.012	0.18

[1]Estimates provide the increase or decrease response in the measured variable for every additional 1 lb increase in milk production.

[2]Quality grade was assigned numerical values with 1 = Prime, 2 = Choice, etc.

pound increase in average milk production. These increases could be due to the impact of milk production on calf weaning weight resulting in heavier calves entering the feedlot. Feedlot ADG was not impacted (P = 0.96) by dam milk production.

Conclusions

Within the herd evaluated, dam milk production increased with cow BW and cow age. However, the reproductive performance in the study was not impacted by level of milk production, suggesting that dam milk production in the current study was not great enough to limit reproduction. Dam milk production had a positive influence on calf pre-weaning growth and BW with additional gains of 0.07 lb/d and overall 13.4 lb additional weaning weight with every pound increase in average milk production. Therefore, it is important to consider the role milk production has on calf pre-weaning performance when striving to produce calves that achieve greater weaning weights. The greater BW at weaning in the offspring of dams with greater milk production, produced an advantage that was maintained throughout the feeding period to produce greater final live BW and HCW.

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Using Pooling to Capture Commercial Data for Inclusion in Genetic Evaluations

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Summary with Implications

Economically relevant traits are those that directly impact commercial-level profit, and as such can only be measured at the commercial level. To capture and use these phenotypes in genetic evaluations, quantifiable relationships that connect routinely collected phenotypes from commercial animals to selection candidates in the seedstock sector are needed. Unfortunately, these relationships are largely unknown. Using pooled genotyping (pooling), relationships between commercial and seedstock animals can be established at a reduced cost. In return, the accuracy of expected progeny differences (EPD) of the seedstock selection candidates are increased and estimated breeding values (EBV) for the pools of commercial animals can be used for management. Seedstock animals with prior low accuracy, those that did not have progeny in genetic evaluations, benefit the most from this strategy. Generally speaking, a pool of any size is better than no information from commercial animals. However, some pool formations are better than others. Pooling in order to minimize phenotypic variation using pool sizes of 10 or greater in order to optimize EPD/EBV accuracy and cost is recommended.

Introduction

Although genetic change in economically relevant traits (ERT) that directly impact profit at the commercial level is the goal, genetic evaluations primarily utilize phenotypes collected within the seedstock sector of the beef industry. Thus, the EPD produced are for indicator traits. However, millions of ERT are collected annually within the commercial segments of the beef industry (feedlots, packing plants, commercial cow/calf herds). This information is rarely included in genetic evaluations due to the inability to connect commercial animals and seedstock selection candidates through known pedigrees. Relationships do exist between these groups of animals, but pedigree information is often unknown or incomplete. Relationships could be resurrected with genomics. However, it would require all commercial animals with records to be genotyped in order to estimate the relationships, which would be costly. An optimal solution would be to collect the ERT from commercial animals and estimate relationships between commercial animals and seedstock animals in an economical manner for use in genetic evaluations. Pooling data, genotypes and phenotypes, has been used to reduce the cost of genotyping while allowing for the inclusion of phenotypes that are typically only observed at the commercial level in genetic evaluations. Therefore, the objectives of this paper were to quantify the impact of pool size, method of assigning animals to pools, and generational gaps between the genotyped seedstock and commercial animals on the resulting accuracy of EBV of parents and pools using simulation.

Procedure

A beef cattle population consisting of 15 generations (n=32,000) was simulated to have a phenotype with a heritability of 0.4, similar to most growth and carcass traits, and the markers mimicked those from a 50k single nucleotide polymorphism (SNP) panel. Individuals from generation 15 were considered commercial animals and included in pools. In practice, a pool represents a group of animals whose DNA has been equally combined and genotyped as a single sample and whose phenotype is the mean of the animals included in the pool. As simulated, the observed genotype and phenotype of the pools were mean values of the individuals that made up the group. Pool sizes included 2, 10, 20, 50, or 100 individuals, resulting in 1,000, 200, 100, 40, or 20 pools, respectively. Additional scenarios were included where individuals from generation 15 were individually genotyped and phenotyped and where the progeny information did not enter the evaluation at all (as if the commercial progeny did not have any information recorded). Pool assignments were determined in three ways: 1) randomly, 2) minimizing phenotypic variation within pools which led to individuals with similar phenotypes being grouped together, and 3) uniformly maximizing phenotypic variation within pools which led to the least variation across pools. Generational gaps in genotyping were induced by masking the genotypes of individuals born in generations 11 through 14 given, in practice, not all seedstock ancestors are genotyped. Four scenarios were considered: individuals up to and including those born in generation 11 were genotyped (Gen11); up to and including those born in generation 12 were genotyped (Gen12); up to and including those born in generation 13 were genotyped (Gen13); and up to and including those born in generation 14 were genotyped (Gen14). Estimated breeding values were generated from a single-step genomic best linear unbiased prediction model. This model combines relationships derived from both genomics and traditional pedigrees into a single relationship matrix which allows for estimation of EBV in one step. The accuracy of the EBV of sires/dams born in generations 11, 12, 13 or 14 and the pools were assessed as the correlation of the EBV with true breeding values. As the accuracy becomes closer to 1, the EBV are better predictors of the true genetic merit of the animals/pools. The simulations were replicated 5 times; results were averaged over the 5 replicates.

Results

Figure 1 depicts the EBV accuracies of sires by generation of birth that resulted from different generational gaps in geno-

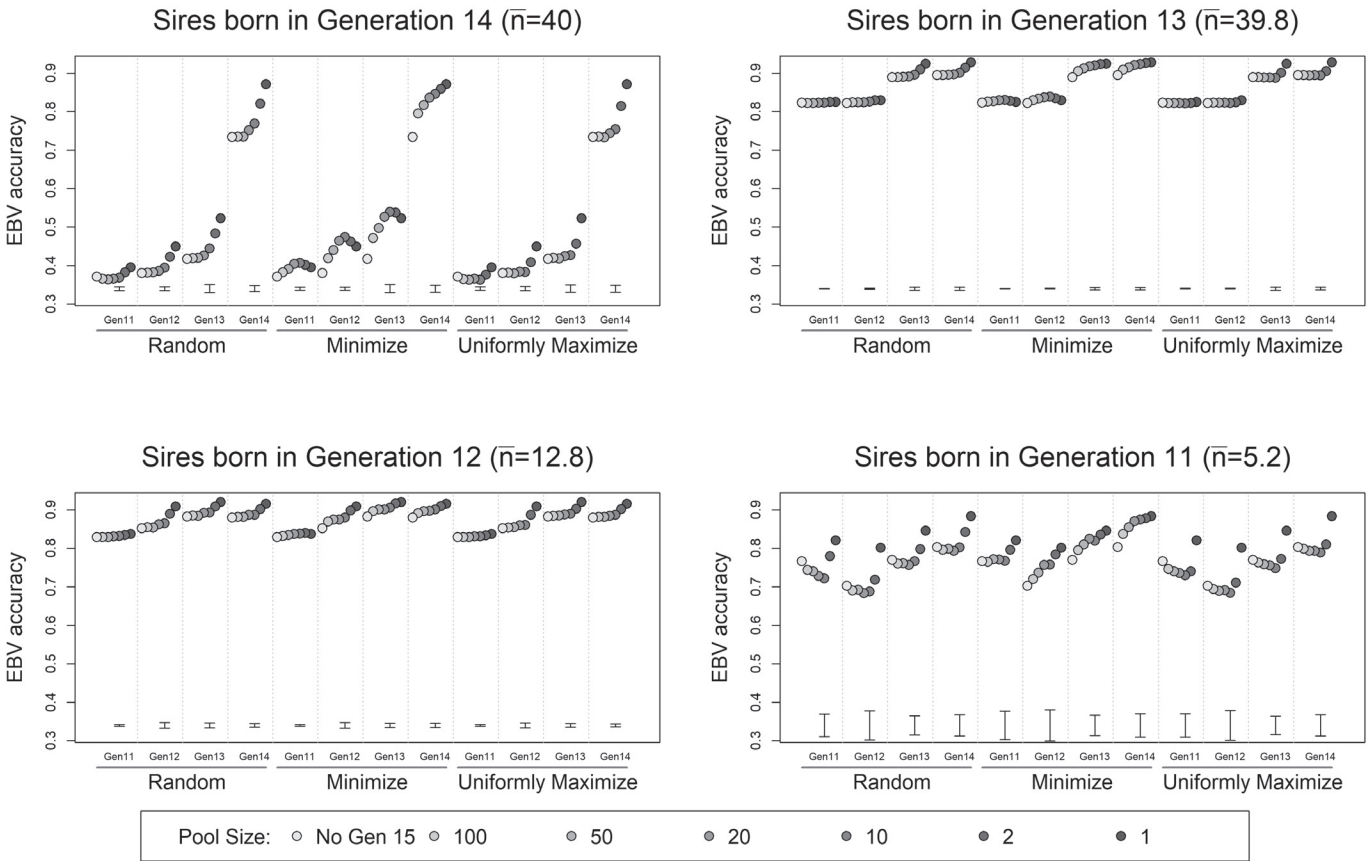

Figure 1. Estimated breeding value (EBV) accuracies of sires (estimated as the correlation between true breeding value and EBV) by generation of birth that resulted from different generational gaps in genotyping (Gen11 = individuals up to and including those born in generation 11 were genotyped; Gen12 = individuals up to and including those born in generation 12 were genotyped; Gen13 = individuals up to and including those born in generation 13 were genotyped; Gen14 = individuals up to and including those born in generation 14 were genotyped), pooling strategies (Random = randomly allocated to pools; Minimize = minimize phenotypic variation within pools; Uniformly Maximize = uniformly maximize phenotypic variation within pools), and pool sizes (No Gen 15 = progeny records from generation 15 did not enter the evaluation) with error bars along x-axis

typing, pooling strategies, and pool sizes; accuracies of dams and grand dams/sires are not shown.

Pooling strategy

Random assignment and uniformly maximizing phenotypic variation within pools led to similar results. Minimizing phenotypic variation within pools led to larger EBV accuracies than the other two scenarios. The largest differences were found in sires born in generation 14 where minimizing phenotypic variation resulted in an increase of EBV accuracy of 8% and 9% compared to random assignment and uniformly maximizing variation, respectively. Therefore, the ways in which pools are constructed does impact the accuracies of prediction.

Pooling size

Pool size also had a considerable impact on EBV accuracy. When pools were formed by allocating animals at random or by uniformly maximizing variation, EBV accuracy was reduced compared to having individual data with the exception of pool sizes of 2. Overall, even though there was a reduction in EBV accuracy resulting from pooling compared to individual data, the reduction was not statistically significant when pools were designed to minimize phenotypic variation.

EBV accuracy of pools

Including pools in the evaluation results in EBV for the pools themselves. The EBV accuracy of pools were significantly impacted by pool size and the interaction between pool size and pooling strategy. Accuracy of EBV of the pools decreased as pool size increased when pools were formed by randomly allocating animals or when animals were assigned to pools to uniformly maximize phenotypic variation. The opposite trend was observed when pools were formed by minimizing phenotypic variation, pool sizes of 100 led to the largest EBV accuracies. This result is because the average phenotype of the pools more closely reflected the average true breeding value of the pool as the pool size increased.

Generational gaps in genotyping

The EBV accuracies of sires and dams because of pooling were generally higher than if no data from generation 15 entered the evaluation. In other words, some

information from commercial progeny, even if the records are pooled, is better than no information from the commercial progeny. This was consistent whether the sires or dams in question were genotyped or were not. However, EBV accuracies for sires/dams were larger if the sires/dams in a particular generation were genotyped compared to if they were not genotyped. The largest increase in EBV accuracy resulting from the sire/dam being genotyped was observed with sires and dams born in generation 14. The increase in EBV accuracy from when sires were and were not genotyped was not as large for sires born in generations 11, 12 or 13 because EBV accuracy of those sires were already relatively high due to additional progeny that entered the evaluation individually. Dams, on the other hand, had larger increases in EBV accuracy from when they were and were not genotyped compared to sires born in the same generation because they had only one progeny per generation. Thus, additional information had a large impact.

Conclusions

The accuracies presented from this simulation represent the theoretical maximum EBV accuracies; realized EBV accuracies resulting from pooling may be less due to lab and genotyping errors. However, the results presented herein show the potential use of pooling data at the commercial level for use in genetic evaluations in an economical manner.

Pooled phenotypes and genotypes can be a potential solution to economically include millions of commercial phenotypes that are currently not able to be used in genetic evaluations. Of the three pooling scenarios simulated, pooling in order to minimize phenotypic variation within pools, meaning to group phenotypically similar individuals together, led to the largest EBV accuracies of sires, dams, and of the pool themselves. When pools were constructed this way, pool sizes of 2, 10, 20, or 50 did not generally lead to differences in EBV compared to when progeny were individually genotyped and phenotyped. These EBV accuracies herein represent a theoretical maximum as in practice, it would likely not be possible to minimize phenotypic variation across contemporary groups. The EBV accuracies in practice will likely fall between those of random pooling and minimizing phenotypic variation. Sires with prior low EBV accuracy – those who do not have progeny that enter the genetic evaluation individually- benefit the most from pooling data in terms of increasing EBV accuracy. Overall, all seedstock animals benefit by utilizing commercial progeny with true ERT recorded. The EBV for the pools could be used to inform future management or marketing decisions.

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Categorization of Birth Weight Phenotypes for Inclusion in Genetic Evaluations Using a Deep Neural Network

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Summary with Implications

Birth weight serves as a valuable indicator of the economically relevant trait calving ease. However, the method used to collect birth weight data can impact the amount of phenotypic variation within a contemporary group and could impact subsequent genetic predictions of both birth weight and calving ease. The aim of this project was to investigate the use of a Deep Neural Network to categorize birth weight contemporary groups based on data quality and to determine the impact on the ranking of animals for calving ease Expected Progeny Differences (EPD). Although most birth weight contemporary groups were classified as real, some contemporary groups were classified as having been generated from a hoof tape or as fabricated. Across the entire population, the removal of contemporary groups where birth weights were clearly classified as fabricated did not impact the genetic prediction for calving ease, however, for animals with higher accuracy associated with their calving ease Expected Progeny Differences, the impact was greater leading to a change of 1 to 2 units in Expected Progeny Differences. Results suggest that a well-trained Deep Neural Network can be effectively used to classify data based on quality metrics prior to inclusion in routine genetic evaluation.

Introduction

Birth weight (BW) serves as a valuable indicator of the economically relevant trait calving ease (CE). More germane to the issue of birth weight data collection is the fact that many bull buyers rely on actual birth weight values as a primary selection criterion. This, in conjunction with a real or perceived obligation to record a birth weight even if birth weight recording did not occur, could potentially lead to fabricated birth weight phenotypes. Even with a desire to contribute valuable data to genetic evaluations, producers may not have the labor required to physically weigh every calf born and thus might use hoof tapes or simply guess weights. The process used to generate birth weight data impacts phenotypic variation and could impact subsequent genetic predictions of both BW and CE. The aim of this project was to investigate the use of an Artificial Intelligence algorithm called a Deep Neural Network (DNN) to categorize contemporary groups based on data quality and to determine the impact on the ranking of animals for CE EPD.

Procedure

Contemporary groups (CG; n=1,200,000) were simulated including individual animal birth weight, sex and age of dam. Twelve possible classifications for CG were assumed that could impact CG phenotypic variance, including weights recorded with a digital scale (REAL), hoof tape (TAPE), those that were fabricated (FAB), and those that were generated with a mixture of methods (DIRTY; e.g., some real weights but missing values were fabricated). Within these four broad categories, CG were further delineated based on variation in age of dam, and the increments of birth weight phenotypes (e.g., 2 or 5-lb increments). These twelve types were later combined to make 4 CG types that would ultimately be used in genetic evaluations (Table 1). Contemporary groups had a minimum of 10 and a maximum of 500 animals. The simulated CG information were used as input variables for the training (80% of the CG) and testing (20% of the CG) of a Deep Neural Network with the goal of accurately and consistently predicting the CG type. This process was replicated 10 times. Multiple parameters of the DNN were tested and compared using both accuracy and precision (consistency) in the simulated data and the final model was chosen based on these two criteria. The final DNN model was used in the prediction of the CG types for birth weight from the American Hereford Association (n=46,177 CG).

The final prediction of the type of each CG was based on the mode of the 10 replicates. Agreement scores were calculated and defined by the proportion of replicates that led to the final CG type prediction. For example, if nine of the ten DNN replicates predicted a CG to be REAL, then the agreement score was 90%.

The impact of removing records from CG classified as FAB from the four categories on resulting CE EPD was investigated. Calving ease direct (CED) and calving ease total maternal (CEM) EPD were calculated using a multi-trait animal model including birth weight and calving score data and implemented using the BOLT software.

Results

The majority of CG were classified as REAL or TAPE (70.66% and 16.27% of the total CG; Table 1). As expected, the lowest phenotypic variance was for FAB CG (12.87 lb^2), while REAL and TAPE CG had the highest and intermediate variances (76.94 lb^2 and 33.27 lb^2), respectively. From these results, approximately 80% of the predictions were classified as "Excellent", meaning that of the 10 replicates, the DNN classified the CG the same at least nine times showing a high degree of confidence in the prediction.

A high correlation was observed for CED and CEM EPD (0.91 and 0.86, respectively) between the case when no corrective action was taken (all records used) and when BW and CE records of animals from CG predicted as being FAB were removed. Only records from CG with agreement of 90% or greater were removed. However, Table 2 shows the distribution of animals by change in CE EPD between the two cases mentioned above. Animals with moderate to higher accuracy (Beef Improvement Federation scale) for CE EPD appear to be

Table 1. Summary statistics of real birth weight (BW) for combined predicted contemporary group (CG) types and the percentage of CG by agreement categories (Excellent= >=90%; Good >=70% and < 90%; Moderate= >=50% and < 70%;Poor= <50%).

							Agreement[3]			
Type[1]	% CG	% Animal	Mean BW	Var BW	Mean CG Size	Var AOD[2]	Excellent	Good	Moderate	Poor
REAL	70.7	73.8	84.2	76.9	29.4	3.2	87.8%	7.5%	4.5%	0.2%
TAPE	16.3	13.7	79.3	33.3	23.7	3.0	52.1%	25.4%	21.0%	1.4%
FAB	7.0	6.0	78.7	12.9	23.9	2.9	60.7%	20.2%	17.4%	1.7%
DIRTY	6.0	6.5	81.4	63.3	30.5	3.5	83.9%	9.1%	6.4%	0.6%
Mean			82.8	59.5	28.2	3.15	79.9%	11.4%	8.2%	0.5%

[1] REAL=real groups collected with a digital scale; TAPE=groups collected with a hoof tape; FAB=Fabricated weights; DIRTY= A mixture of types.

[2] AOD=Age of dam

[3] Agreement refers to the proportion of replicates that produced the same prediction.

Table 2. Percentage of animals by calving ease direct (CED) EPD change and CE EPD accuracy level.

	Levels of CED EPD accuracy using all records				
CED EPD units	=<0.10	>0.10 & <=0.25	>0.25 & <=0.35	>0.35 & <=0.55	=>0.55
<=1 unit	78.0%	48.7%	34.7%	32.7%	34.7%
> 1 & <=2 unit	19.9%	28.5%	32.4%	31.9%	31.9%
> 2 & <=3 unit	1.3%	12.0%	17.4%	20.2%	22.7%
> 3 & <=4 unit	0.4%	5.3%	8.2%	9.2%	5.6%
> 4 & <=5 unit	0.2%	2.6%	3.9%	3.7%	3.5%
>5 unit	0.3%	2.9%	3.3%	2.2%	1.4%
No. Animals	12,596	2,770,882	508,658	12,820	141

impacted the most. This is due to the fact that they have the greatest number of progeny and, consequently, are the most at risk of having records of descendants removed.

Conclusions

Given these results, it is recommended to remove birth weight and calving ease phenotypes from the genetic evaluation for animals belonging to contemporary groups predicted as FAB with a consistency of classification of 90% or greater.

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Genetic Parameter Estimates for Age at Slaughter and Days to Finish in a Multibreed Population

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Summary with Implications

The objective of this study was to estimate genetic parameters for age at weaning, days to finish, and age at slaughter and their relationships with carcass traits. Heritability estimates using univariate models for days to finish and age at slaughter when adjusted to different endpoints ranged from 0.33 to 0.39 and 0.52 to 0.59, respectively. The genetic correlations between age at weaning and days to finish ranged from -0.26 to -0.43. Results indicate days to finish and age at slaughter are moderately heritable and would respond favorably to selection. Days to finish, even when adjusted to various endpoints, displays minimal phenotypic variation. Age at slaughter, although more variable than days to finish, is comprised of multiple identifiable sub-traits including age at weaning and days to finish. Consequently, a selection program for improved age at slaughter should consider the impact on the component traits.

Introduction

Considerable effort and expense have been spent on collecting individual animal feed intake on immature seedstock animals as a means of producing Expected Progeny Differences (EPD) for dry matter intake as indicators of feed consumption in commercial growing animals. Dry matter intake EPD represent the only predictions of genetic merit for costs associated with finishing cattle. However, the amount of feed consumed only represents a portion of the variable costs of finishing cattle, with other costs including yardage, morbidity, and mortality. The number of days cattle spend in a feedlot to reach a desired endpoint (e.g., weight, fatness, quality grade) is a function of the amount of feed they consume, rate of growth, and rate of tissue deposition. Reducing the amount of time on feed needed to reach a desired endpoint would be economically advantageous. However, the choice of the finish endpoint depends on the biological type of cattle being marketed and the marketing systems available to the owners. The objective of this study was to estimate genetic parameters for age at weaning (AAW), days to finish (DtF), age at slaughter (AAS), and their relationships with growth and carcass traits including; adjusted fat thickness (AFT), hot carcass weight (HCW), marbling score (MARB), ribeye area (REA), and final weight (FW).

Table 1. Summary statistics for data utilized within analyses.

	Mean (SD)			
Trait[1]	Steers		Heifers	
AAS	451	(18.4)	433	(20.4)
AAW	164	(18.9)	151	(17.0)
AFT	0.52	(0.19)	0.49	(0.17)
DtF	287	(11.0)	281	(15.2)
FW	1380	(134)	1208	(113)
HCW	871	(88.0)	767	(74.5)
MARB	506	(77.0)	501	(66.5)
REA	13.6	(1.58)	13.7	(1.48)

[1]AAS = age at slaughter, the number of days from birth until harvest (days), AAW = age at weaning, the number of days from birth until weaning (days), AFT = adjusted fat thickness (in), DtF = days to finish, the number of days from weaning until harvest (days), FW = final live weight (lbs), HCW = hot carcass weight (lbs), MARB = marbling (score), REA = ribeye area (in^2).

Procedure

All animal procedures followed U.S. Meat Animal Research Center (USMARC) standard operating procedure and cattle were treated according to Federation of Animal Science Societies guidelines. For the Germplasm Evaluation Program (GPE) generations, purebred AI sires were mated to purebred or crossbred dams to generate purebred and crossbred steers and heifers and purebred and F_1 bulls. The bulls were mated to the purebred and half-blood females to produce purebred, half-blood, and F_1[2] steers and heifers. All germplasm introduced into the population entered through AI. Animals from the 8 cycles included only spring-born records whereas the advanced generations of GPE included spring and fall calving records. All heifers were bred via natural service during GPE cycles. Data were from steers and heifers (n=7,747) from the GPE at the USMARC (**Table 1**). The average age of the animals at feedlot entry was 162 days or equivalent to their AAW. All traits were analyzed with univariate and bivariate animal models using ASReml. Fixed effects fitted for all models included contemporary group (concatenation of birth year, birth season, sex, and experimental treatment group), breed covariates, and direct heterosis. Different endpoints for AAS and DtF were also investigated by fitting fixed linear covariates of AFT, HCW, MARB, REA, and FW.

Results

Univariate heritability estimates for AAS and DtF ranged from 0.52 to 0.59 and 0.33 to 0.39, respectively (**Table 2**). Covariates of MARB and AFT led to the highest and lowest, respectively, heritability estimates for AAS and DtF. The genetic correlations between AAW and DtF ranged from -0.26 to -0.43, depending on the chosen endpoint

Table 2. Genetic parameter estimates (SE) for univariate models for age at slaughter (AAS[1]) and days to finish (DtF[2]).

	Response Trait	
	AAS	DtF
Covariate[3]	h^2	h^2
AFT	0.52 (0.04)	0.33 (0.03)
FW	0.57 (0.04)	0.38 (0.03)
HCW	0.56 (0.04)	0.38 (0.03)
MARB	0.59 (0.04)	0.39 (0.03)
REA	0.59 (0.04)	0.38 (0.03)
None	0.59 (0.04)	0.38 (0.03)

[1]AAS = age at slaughter, the number of days from birth until harvest.

[2]DtF = days to finish, the number of days from weaning until harvest.

[3]AFT = adjusted fat thickness (in), FW = final live weight (lbs), HCW = hot carcass weight (lbs), MARB = marbling (score), REA = ribeye area (in^2).

Table 3. Genetic correlations (SE) for multivariate models for age at weaning (AAW)[1] and carcass traits.

Response Trait			
1	2[2]	Covariate[3] for 2	r_g
AAW	DtF	AFT	-0.26 (0.05)
		FW	-0.42 (0.04)
		HCW	-0.43 (0.04)
		MARB	-0.43 (0.04)
		REA	-0.41 (0.04)
		None	-0.41 (0.04)

[1]AAW = age at weaning, the number of days from birth until weaning.

[2]DtF = days to finish, the number of days from weaning until harvest.

[3]AFT = adjusted fat thickness (in), FW = final live weight (lbs), HCW = hot carcass weight (lbs), MARB = marbling (score), REA = ribeye area (in^2).

for DtF (**Table 3**). Selection to improve DtF could, in turn, lead to increases in AAW. The phenotypic variation in AAW is likely due to variation in calf birth date which is related to the date at which the dam conceived. Further research is required to investigate the addition of maternal additive genetic, heterosis, and breed effects for AAW and AAS.

Implications

Results indicate that AAS and DtF are moderately heritable. The choice of the finish endpoint, and consequently the covariate included in the model for AAS and DtF, is dependent on the marketing scheme being targeted, although the most likely choices would be carcass weight or adjusted fat thickness. Both proposed traits, DtF and AAS, have issues that need to be considered before implementation in a genetic evaluation. The general lack of variation in DtF due to the reduced variation in the unadjusted number of days on feed potentially limits this traits utility to make genetic progress for overall feedlot efficiency. Although AAS displays greater variation, the sources of variation need to be fully quantified to avoid unintended correlated responses to selection.

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Effects of Monensin and Protein Type on Performance of Yearling Steers Grazing Smooth Bromegrass Pastures

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Summary with Implications

Two-year study evaluated the effects of monensin on protein type, either rumen degradable or rumen undegradable, with yearling steers grazing smooth bromegrass pastures. Steers were supplemented soybean meal (rumen degradable protein) or non-enzymatically browned soybean meal (rumen undegradable protein) at isonitrogenous levels to dried distillers grains plus solubles provided at 0.50% BW. Likewise, steers were provided either zero or 200 mg/hd/d of monensin for a total of six treatments with a 2 × 3 (no protein, RDP, or RUP) factorial design. There was no interaction of monensin by protein type. Providing monensin to grazing yearlings did not improve ADG; however, monensin numerically improved steers daily gain by 7.64% when no protein supplement was provided. Previous research has demonstrated monensin supplementation in yearling grazing systems has improved rate of gain, though the improvement may be minimal. Both rumen degradable and rumen undegradable protein types improved daily gain by 31.15% compared to no protein supplement. Providing a rumen undegradable protein supplement improved daily gain by 5.63% compared to rumen degradable protein supplement. Therefore, providing protein, and especially a rumen undegradable protein, improved yearling steer performance on smooth bromegrass pastures.

Introduction

Monensin is a carboxylic polyether ionophore that selectively inhibits Gram-positive bacteria. In ruminant animals, monensin will alter the ratio of volatile fatty acids in the rumen, increasing propionate production and reduce acetate and butyrate production. Propionate can be converted to glucose, unlike acetate and butyrate. This provides the ruminant animal with more energy from increased glucose supply when using monensin.

Previous research has suggested monensin elicits a protein and energy response to average daily gain (ADG). Greater concentrations of glucogenic propionate may spare some glucogenic amino acids from degradation by the liver. Likewise, monensin decreases rumen microbial proteolytic activity. Therefore, some protein destined for rumen degradation may escape the rumen and become available to the animal. The purpose of this study was to observe the protein response of monensin when yearling steers grazing smooth bromegrass pastures were supplemented a rumen degradable protein (RDP) and rumen undegradable protein (RUP) types. To measure the impact of monensin on protein degradation in the rumen, RDP would be compared to RUP, a protein type that has far less degradability in the rumen. The hypothesis was that cattle supplemented monensin with either protein type (RDP or RUP) would have greater average daily gain (ADG) compared to cattle supplemented protein (RDP or RUP) without monensin.

Table 1. Ingredient composition of common supplements[1]

	Year 1		Year 2	
	0	200	0	200
Ingredient Composition, %				
Soybean Hulls	93.9	93.7	63.7	62.8
Dried Molasses	4.2	4.2	14.1	14.1
Liquid Molasses	-	-	4.1	4.1
Limestone	1.0	1.0	-	-
Salt	0.3	0.3	17.5	17.5
Beef Trace Mineral	0.66	0.66	0.66	0.66
Rumensin 90[2]	-	0.2205	-	0.2205

[1]Provided at 1 lb/hd/d (DM basis).

[2]Monensin provided to target 0 or 200 mg/hd/d (DM basis).

Procedure

A two-year experiment was conducted utilizing 144 yearling steers each year (year one initial BW = 746 lb, SD = 51 and year two initial BW = 717 lb, SD = 18) to study the effects of monensin on supplemented protein type, rumen degradable protein (RDP) or rumen undegradable protein (RUP), in a randomized complete block design on smooth bromegrass pastures. The study was arranged as a 2 × 3 factorial design. Treatments consisted of monensin at zero or 200 mg/hd/d and protein type of soybean meal (RDP) or non-enzymatically browned soybean meal (RUP) with a negative control consisting of no additional protein source (CON). Supplement was provided daily. A common supplement was provide to all groups containing soyhulls, molasses, salt, limestone (year 1 only), and mineral at 1 lb/hd/d (DM basis; Table 1). If steers were assigned to monensin, it was included in the common supplement and displaced soyhulls. If supplement included protein, the amounts were calculated to match crude protein supplied from DDGS (34% CP) at 0.50% of body weight (BW) for both soybean meal and non-enzymatically browned soybean meal (0.33 and 0.31% BW, respectively). Either protein supplement was added to the common supplement before being fed to their respective

Table 2. Performance of yearling steers grazing smooth bromegrass pastures

	Monensin Inclusion[1]									
	0			200						
	Protein Type[2]						SEM	*P*-value[3]		
Item	CON	RDP	RUP	CON	RDP	RUP		P	M	P × M
Head, n	48	48	48	48	46	48				
Pastures, n	7	7	7	7	7	7				
Initial BW, lb	731	733	731	732	733	730	1.6	0.43	0.86	0.82
Ending BW, lb	956[c]	1033[b]	1041[a]	975[c]	1029[b]	1050[a]	7.1	<0.01	0.19	0.28
ADG, lb/d	1.44[c]	1.92[b]	1.98[a]	1.55[c]	1.89[b]	2.04[a]	0.043	<0.01	0.17	0.26

[1]Monensin targeted at zero or 200 mg/hd/d (DM basis).

[2]CON = control with no protein supplement, RDP = rumen degradable protein from soybean meal, RUP = rumen undegradable protein from soypass

[3]P = protein main effect, M = monensin main effect, P × M = protein × monensin interaction

[abc]Means in a row with uncommon superscripts differ ($P \leq 0.05$)

group. Each year, steers were assigned to one of six treatments with four replications per treatment and six steers per pasture. Pastures consisted of approximately six acres and divided into three equal paddocks and rotationally grazed for 154 d (year one) and 161 d (year two) from May to October. In both years, all pastures were fertilized in mid-April with 80 lb N/acre. The grazing period was divided into cycles with the first cycle lasting approximately 31 d and cycles two through four lasting approximately 38 d, cycle five only occurred in year one and lasted approximately 23 d. In order to update supplement amount, BW was measured at the end of each cycle and shrunk four percent to account for gut fill.

Upon initiation of the trial steers were limit-fed a common diet containing 50% Sweet Bran (Cargill Corn Milling, Blair, NE) and 50% alfalfa hay (DM basis) at 2% of BW for five days followed by three days of weighing. The average of the three d weights served as initial BW. The same protocol was replicated at the end of the study to measure ending BW. Steers were implanted with 40 mg trenbolone acetate and 8 mg estradiol (Revalor-G; Merck Animal Health, De Soto, KS).

One steer was removed from RDP with monensin in year two due to bodily injury. One steer from treatment RDP with monensin in year two died with cause of death unknown. Both steers were replaced with non-experimental steers to maintain stocking rate for those pastures. Due to frequent inadequate consumption of supplement by one pasture in replication two of year two data from entire replication was removed from analysis. As a result, performance data were analyzed with seven complete replications.

Initial BW, ending BW, and ADG results were analyzed using GLIMMIX procedure of SAS (9.4, SAS Institute Inc., Cary, NC). Treatment, pasture block and year served as fixed effects in the model. The model included protein supplement, monensin inclusion level, the interaction of protein supplement and monensin inclusion level, pasture block, and year. Pasture nested within year was the experimental unit. Treatment means were calculated using the LSMEANS option of SAS. Treatment differences were significant at $\alpha \leq 0.05$ and tendencies were discussed when $0.05 < \alpha \leq 0.10$.

Results

There were no interactions detected for ending BW or ADG between protein type and level of monensin ($P \geq 0.26$; Table 2). Monensin inclusion had no effect on ending BW or ADG ($P \geq 0.17$). However, supplementing steers with 200 mg/hd/d of monensin with no protein supplement numerically improved ADG by 7.64% when fed without protein supplement. This response to monensin, an increase of 0.11 lb daily gain, was expected and agrees well with recent literature. When fed in combination with a protein supplement, the monensin response was 0 to 3% improvement in ADG. These data suggest further investigation into the interaction of protein supplement and monensin supplementation is required.

A protein type response was observed ($P < 0.01$) for ending BW and ADG. Steers provided protein (RUP or RDP) were, on average, 73 lb heavier at the end of the grazing season compared to CON. Steers provided protein, either RDP or RUP, had a 31.15% (0.46 lb/d) improvement in ADG compared to CON steers. Similarly, steers consuming a RUP supplement were 15 lb heavier than steers consuming a RDP supplement (1045 vs. 1030, respectively; $P = 0.01$). By supplementing RUP, steers gained 5.63% (0.11 lb/d) more than steers provided RDP. Steers responded in large part to protein supplementation (either RUP or RDP). Depending on the individual producer's goals, protein supplementation could be considered for improvements in ADG when grazing yearling steers on smooth bromegrass pastures.

Conclusion

Overall, supplementing protein, either RDP or RUP, to yearling steers grazing smooth bromegrass will improve ADG. Additoinally, providing an RUP type of protein will supply more dietary metabolizable protein and improve animal performance compared to an RDP type. Overall, there was no response to monensin. However, when monensin was included without protein supplementation, ADG was improved. Because the expected response to monensin relative to protein supplement is small, more replication may be necessary to detect a response in animal performance. Supplementing with monensin, RDP, RUP, or no supplement at all are viable options that producer's should consider when evaluating their goals and target endpoints for their yearling cattle.

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Impact of Masters Choice Corn Silage on Nutrient Digestion in Growing Cattle

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Summary with Implications

A digestion study was conducted to evaluate Masters Choice corn silage hybrids on nutrient digestibility in growing beef steers. The three hybrids evaluated were a conventional hybrid (CON) commonly grown in Eastern Nebraska which served as the control, Masters Choice hybrid MCT6365 RIB (MC1) that has been selected to improve fiber and starch digestion and Masters Choice hybrid MCT6733 GT3000 (MC2) selected to improve fiber digestion. Treatment diets consisted of 80% of the diet dry matter (DM) of each corn silage hybrid. Steers fed MC1 corn silage had the greatest organic matter (OM), energy digestibility, and digestible energy (DE) content of the diet. Feeding MC2 resulted in the lowest OM, starch, and energy digestibility and dietary DE content. Steer energy digestion (OM, DE) was intermediate to MC1 and MC2 for CON silage. Results indicated that feeding MC1 corn silage at 80% of the diet DM improved digestion and energy availability to the steers, which allowed greater average daily gain and improved feed conversion observed in the corresponding growing trial, while the opposite was true for MC2.

Introduction

In many studies, feeding high inclusions of corn silage has been shown to be more economical in growing and finishing cattle, especially when corn price is high, despite poorer gain and conversion. Methods that improve corn silage quality would benefit cattle backgrounders and feedlot operations that feed greater inclusions of silage. Evaluation of corn silage digestibility is normally done using laboratory techniques to predict the performance if fed to cattle, which may or may not predict actual performance when fed to cattle. The objective of this study was to evaluate two Masters Choice (Anna, IL) hybrids that have been selected to improve fiber plus starch digestion (MC1) and fiber digestion (MC2) on nutrient intake and digestion in cattle. These Masters Choice hybrids were compared to a hybrid (Farm Choice, CON) commonly grown in Eastern Nebraska.

Procedure

Three hybrids of corn silage were grown, harvested and stored as described in the performance study (*2020 Nebraska Beef Cattle Report*, pp. 24–26). Six ruminally cannulated beef steers (crossbred, 12-month-old) were utilized in a 3×6 Latin rectangle design with three treatments per period. The steers were housed in individual concrete slatted pens with *ad libitum* access to feed and water. Steers were assigned randomly to the same three dietary treatments as described in the performance study (*2020 Nebraska Beef Cattle Report*, pp. 24–26): 80% of diet dry matter (DM) of CON (Farm Choice, served as control), MC1 (selected to improve fiber and starch digestion, Masters Choice MCT6365 RIB; Anna, IL) and MC2 (selected to improve fiber digestion, Masters Choice MCT6733 GT3000; Anna, IL) corn silage in each diet, and the rest included 15% modified distillers grains plus solubles (MDGS), 5% supplement. Supplement was formulated to provide 200 mg rumensin/steer daily (assuming a dry matter intake (DMI) of 22 lb) and 0.5% DM of urea. The study consisted of six periods, 21d in length with 14 days of adaptation and 7 days of collection. Diets were mixed twice weekly and stored in a cooler to ensure freshness. Steers were fed once daily at 0700 h, and feed refusals were removed and weighed daily prior to feeding. Refusals were collected on day 16 to day 19, dried in 140 °F forced-air oven for 48 hours to correct DM intake. Samples of individual ingredients were taken prior to diet mixing during collection week, composited by period, lyophilized, and ground through a 1-mm screen using a Wiley mill.

Steers were dosed twice daily, on day 8 to day 20, intraruminally with titanium dioxide (16 g/day) to determine fecal output. Fecal grab samples were taken at 0700, 1100, 1500, and 1900 h and composited on wet basis daily on day 17 to day 20. The lyophilized and ground (1 mm) daily composites were then composited on a dry weight basis by steer within each collection period. Fecal samples were analyzed for titanium dioxide concentration and used to determine total fecal output. Feed and fecal samples were analyzed for gross energy content (calories/g) using a bomb calorimeter. Digestible energy (DE) was calculated by subtracting the fecal energy from the total gross energy intake. Nutrients such as dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF), and starch content of fecal and feed samples were also analyzed and calculated for total tract digestibility.

Ruminal pH was recorded every minute using wireless pH probes submerged into the rumen, from day 16 to 20. Ruminal fluid samples were collected using a vacuum hand pump, on day 19 of each period at 0730, 1130, 1530, and 1930 h for volatile fatty acids (VFA) analysis. Ruminal VFA samples were analyzed by gas chromatography. Each corn silage (lyophilized and ground through 2 mm) and dry bran (1.25 g) sample were weighed into 5 × 10 cm in-situ bags. In-situ bags (4 per sample) were submerged into the rumen for 28 hours on day 20 at 1100 h of each period. In-situ NDF disappearance was determined, and NDF analyzed using the Ankom Fiber Analyzer.

Apparent total tract digestibility of the nutrients, total nutrient intake, and in-situ NDF disappearance were analyzed using the PROC MIXED procedure of SAS 9.4 (SAS Institute, Inc., Cary, NC, USA), with

Table 1. Dietary nutrient intake and total tract digestibility for steers fed Masters Choice corn silage hybrids compared to a conventional hybrid as a control

	Treatments[1]				
Item[2]	CON	MC1	MC2	SEM	*P*-Value
DM					
Intake, lb	18.1	17.7	18.1	0.64	0.88
Digestibility, %	68.0	68.8	66.7	1.01	0.24
OM					
Intake, lb	16.7	16.0	16.7	0.61	0.68
Digestibility, %	71.2[ab]	73.1[a]	69.4[b]	1.18	0.02
NDF					
Intake, lb	6.8	6.7	7.3	0.26	0.25
Digestibility, %	48.4	51.5	50.6	2.04	0.45
ADF					
Intake, lb	4.1	4.2	4.2	0.18	0.89
Digestibility, %	42.1	46.5	45.3	2.26	0.34
Starch					
Intake, lb	5.8	5.7	5.5	0.22	0.64
Digestibility, %	97.9[a]	97.3[a]	96.5[b]	0.42	< 0.01
Energy					
Digestibility, %	69.2[b]	71.3[a]	67.5[b]	0.94	0.02
DE, Mcal/day	24.44	24.28	23.82	0.97	0.89
DE Mcal/lb	1.35[ab]	1.37[a]	1.32[b]	0.02	0.07
Bran in situ NDF digestibility, %[3]	51.6[a]	45.1[b]	47.4[ab]	3.99	< 0.01

[a-c] Means in a row with different superscripts are different ($P < 0.10$)

[1] Treatment include CON, conventional corn hybrid of Farm Choice silage serves as control; MC1, corn hybrid of MCT6365 RIB silage, selected for greater fiber + starch digestion; MC2, corn hybrid of MCT6733 GT3000 silage, selected for greater fiber digestion

[2] DM: Dry matter; OM: Organic matter; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; DE: Digestible energy

[3] Incubated in rumen for 28 hours inside cattle fed treatment diets

period and treatment as fixed effect. Rumen VFA data were analyzed using PROC MIXED with treatment, period, hour and treatment by hour interaction included in the model, steer served as random effect. The pH data were by day (average, minimum, maximum, etc) and analyzed using the PROC MIXED procedure with treatment, period, day and day by treatment interaction included in the model and day being considered a repeated measure.

Results

Corn silage hybrid did not impact DM intake ($P = 0.88$; Table 1), which differed from the performance study where steers fed MC2 had the greatest DM intake (*2020 Nebraska Beef Cattle Report*, pp. 24–26). Total tract DM digestibility was not impacted ($P = 0.24$) by treatment although it was numerically greater for MC1, and numerically least for MC2. Treatment had no effect on OM intake ($P = 0.68$), but did impact OM digestibility ($P = 0.02$), with steers fed MC1 having the greatest OM digestibility, steers fed MC2 having the least, and CON fed steers being intermediate. There was no treatment effect observed for NDF and ADF intake of steers fed different hybrids of corn silage ($P \geq 0.25$). Although a numerical increase in NDF and ADF digestibility was observed for both MC1 and MC2 fed steers, a significant difference was not detected ($P \geq 0.34$).

Starch intake was not different across silage hybrid treatments ($P = 0.64$; Table 1). Total tract starch digestibility was impacted by dietary treatment ($P < 0.01$), with the steers fed MC2 having the least starch digestibility, and no difference between CON and MC1 ($P = 0.12$). Energy digestibility ($P = 0.02$) as a percentage and dietary DE content ($P = 0.07$) were significantly different among treatments. Steer fed MC1 had the greatest energy digestibility and dietary DE content, followed by CON, and least for MC2. There was no treatment effect for DE intake of steers fed different hybrids of corn silage ($P = 0.89$). There was no treatment × sample effect ($P = 0.98$) for in-situ NDF digestibility; therefore, treatment effect on corn bran in situ NDF digestibility was reported here and there was a significant effect ($P < 0.01$). Surprisingly, steers fed MC1 had the lowest in situ NDF digestibility suggesting something impacted ruminal digestion of fiber in those cattle, with no difference between CON and MC2. The in situ data observation is not consistent with observed total tract digestion of fiber.

There was no silage hybrid treatment effect ($P \geq 0.55$; Table 2) on average, minimum, and maximum rumen pH parameters. A rumen pH below 5.6 was rarely observed in this study. There was significant difference for magnitude and variation of ruminal pH due to silage hybrid, but these changes were relatively small. There was no treatment effect for molar concentration of acetate, butyrate and total VFA of ruminal fluid ($P \geq 0.11$; Table 3). A significant effect was detected for propionate concentration ($P = 0.09$), with steers fed CON (16.76 mM) having the greatest propionate concentration, followed by MC2 (15.66 mM) and MC1 (14.93 mM) with no difference between each other. The acetate:propionate ratio was greatest for MC2, followed by MC1, and least for CON ($P = 0.01$).

Conclusion

Results suggest that feeding Masters Choice corn silage hybrid MCT6365 RIB (MC1) at 80% of the diet DM improved OM digestibility, energy digestibility and dietary DE content, which explained the improved ADG and feed conversion for steers fed MC1 in a performance study (*2020 Nebraska Beef Cattle Report*, pp. 24–26). Feeding MC2 resulted in numerical decreases in DM, OM, and energy digestibility, which aligned with the numerically lowest ADG and poorest feed conversion of steers fed MC2. These metabolism data align closely with the performance data and suggest that corn hybrid selection can impact nutrient digestion.

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Table 2. Ruminal pH characteristics for steers fed Masters Choice corn silage hybrids compared to a conventional hybrid as a control

	Treatments[1]				
Item[2]	CON	MC1	MC2	SEM	*P* - Value
Minimum	6.20	6.16	6.23	0.05	0.64
Maximum	7.11	7.06	7.02	0.06	0.55
Average	6.70	6.64	6.64	0.05	0.69
Magnitude	0.92[a]	0.90[a]	0.80[b]	0.04	0.06
Variation	0.05[a]	0.04[a]	0.03[b]	0.004	0.08

[a-c] Means in a row with different superscripts are different ($P < 0.10$)

[1] Treatment include CON, conventional corn hybrid of Farm Choice silage serves as control; MC1, corn hybrid of MCT6365 RIB silage, selected for greater fiber + starch digestion; MC2, corn hybrid of MCT6733 GT3000 silage, selected for greater fiber digestion

[2]Average pH over 5 days; Treatment × Day was not significant ($P = 0.31$)

Table 3. Ruminal VFA concentration for steers fed Masters Choice corn silage hybrids compared to a conventional hybrid as a control

	Treatments[1]				
Item[2]	CON	MC1	MC2	SEM	*P* - Value
Acetate, %[3]	64.45	65.33	66.60	1.91	*0.14*
Propionate, %[3]	21.14[a]	20.20[b]	20.08[ab]	1.28	*0.09*
Butyrate, %[3]	10.29	9.92	9.42	0.40	*0.11*
Total VFA, mM	79.28	73.88	78.01	3.54	*0.17*
Acetate:Propionate ratio	3.31[b]	3.43[ab]	3.58[a]	0.19	*0.01*

[a-c] Means in a row with different superscripts are different ($P < 0.10$)

[1] Treatment include CON, conventional corn hybrid of Farm Choice silage serves as control; MC1, corn hybrid of MCT6365 RIB silage, selected for greater fiber + starch digestion; MC2, corn hybrid of MCT6733 GT3000 silage, selected for greater fiber digestion

[2]Average concentration over 4 time points (0730, 1130, 1530, and 1930); hour × Treatment was not significant ($P \geq 0.75$)

[3]Percent of total VFA; difference was compared on molar concentration (mM) basis

Winter Growth Rate and Timing of Marketing on Economics of Yearling Systems

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Summary with Implications

Economic analyses were conducted examining 18 years of Nebraska monthly-average auction data to find the effects of certain management decisions on the profitability of yearling production systems. A 2×2 experimental design was used to examine four possible scenarios. The variables were either fast winter growth (daily gain, 2.0 lb/day) or slow winter growth (daily gain, 0.8 lb/day), and either a September or a July marketing date. In addition to profitability, risk management was also examined in this study. Average profitability of all scenarios was good, ranging from $112 to $143 per calf. Utilizing fast winter growth combined with marketing steers in September was the most profitable scenario.

Introduction

Discussions regarding optimum target rates of gain during winter and the window for selling calves, specifically selling yearlings in July vs. September are common among yearling producers in Nebraska. There are many ways to grow yearlings and every operation is unique in the resources that it has available, thus it is impossible to determine what system is best for all operations. However, it is possible to evaluate the potential impact of the decisions using example scenarios. The economic effects of using different target rates of gain while grazing corn residue in the winter in combination with marketing calves off of grass in July or September have been previously evaluated by using performance data from 3 previous studies and the average market price from 2017 and 2018 (*2020 Nebraska Beef Cattle Report*, pp. 31–34). Their analysis did not show a clear benefit to July vs. September marketing. However, given the limited scope of market data evaluated, the goal of this paper was to further explore these questions using long term historical market data.

Procedure

To evaluate the effects of growth rate in the winter and time of marketing of yearling steers on net profit in Nebraska, the following assumptions were made using animal performance from the *1996 Nebraska Beef Cattle Report*, pp. 51–53. A 506-pound steer was purchased (or retained) in October and then processed and fed a growing ration for 14 days (527 lb end BW). Calves were then wintered by grazing corn residue for 127 days with two amounts of distillers being fed based on data from *2017 Nebraska Beef Cattle Report*, pp. 34–35. For the fast rate of winter gain (FAST) calves were supplemented with 7 lb/d of dry distillers grain and average daily gain (ADG) was assumed to be 2.03 lb/d. For the slow winter gain (SLOW), 1.3 lb/d of dry distillers was supplemented and ADG was assumed to be 0.79 lb/d. A decision point then occurs whether to sell the cattle in February or hold them over for spring (91 days) and summer growing periods. Two choices were evaluated for the summer grazing period, a short 62-day period with marketing occurring in July or a long 120-day period with marketing in September. Calves with lower rates of gain in the winter will compensate in the summer resulting in greater gains on the same forage base than those with high rates of gain in the winter. The growth rate of cattle in the Sandhills of Nebraska decline in the late summer due to reduced forage quality. Thus, gains in early summer will be greater than in late summer. Therefore, in the fast winter growth scenarios, spring ADG was assumed to be 1.5 lb/day with summer growth assumed to be 1.44 lb/d for steers being marketed in July or 1.29 lb/d for steers being marketed in September. For the slow winter growth scenarios, spring ADG was also 1.5 lb/d with summer growth at 2.45 lb/d for steers marketed in July or 2.01 lb/d for those marketed in September (*1996 Nebraska Beef Cattle Report*, pp. 51–53).

Cost assumptions for all scenarios are outlined in Table 1. A 1% death loss was factored into the total wintering cost, as well as a 5.6% interest rate for 0.35 years on the purchase price of the calf. For the winter growing period, cattle were assumed to be grazing on corn residue priced at $0.56/day for both groups plus cost of supplement with either 7 lbs or 1.3 lbs of distillers grains per day (as-fed) priced using an average of the weekly prices from October to February each year from the USDA. For the spring growing period, feed prices were determined based on distillers grains and hay price data for each year from the USDA. A ration of 13 lbs of hay and 2 lbs of distillers grains per day (as-fed) was used to calculate the final spring feed price for all scenarios. Despite the steers on the slow winter system being lighter weight when grazing in the summer their intake as a percent of BW would be greater thus intake would be similar (*2000 Nebraska Beef Cattle Report*, pp 30–31; *2001 Nebraska Beef Cattle Report*, pp 34–36). The cost of summer grass was charged at the same price across scenarios based on historic pasture rental rates in the 2017–2018 Nebraska Farm Real-Estate Market Highlights from the Department of Agricultural Economics at the University of Nebraska-Lincoln. It was assumed that no protein or energy supplement was provided in the summer. The initial value of the calves in October of each year, and value when selling the following July and September of the succeeding year, were determined using LMIC Weekly & Monthly Combined Nebraska Auction Cattle Prices from 1999 through 2017, updated 9/3/2019 (Livestock Marketing Center, Lakewood, Colorado). The total cost of producing the steer (including the initial purchase price) was then subtracted from the sale value of the steer to calculate the net profit.

Table 1. Estimated cost ($/steer)[1] for growing steers with two different rates of winter gain (2.0 or 0.8 lb/d, fast and slow, respectively) and three different marketing times February (end of winter) July, or September over an 18 year period from 1999 through 2017.

	Fast	Slow
Processing	$15	$15
Interest on Animal	$8.79–$29.26 ($14.07)	$8.79–$29.26 ($14.07)
Death Loss (1%)	$4.49–$14.93 ($7.18)	$4.49–$14.93 ($7.18)
Receiving	$26.25	$26.25
Corn Residue	$71.12	$71.12
Distillers	$31.34–$125.37 ($61.04)	$5.82–$23.28 ($11.34)
Mineral	$6.35	$6.35
Feed Interest	$1.47–$2.39 ($1.76)	$1.22–$1.39 ($1.27)
Wintering Cost	**$170–$271 ($203)**	**$142–$176 ($153)**

	Market in July	Market in September	Market in July	Market in September
Spring Feed	$42.97–$150.71 ($66.06)	$42.97–$150.71 ($66.06)	$42.97–$150.71 ($66.06)	$42.97–$150.71 ($66.06)
Spring Yardage	$22.75	$22.75	$22.75	$22.75
Summer Grass	$23.02–$66.62 ($38.22)	$44.56–$128.95 ($73.97)	$23.02–$66.62 ($38.22)	$44.56–$128.95 ($73.97)
Interest on Feed	$0.60–$1.40 ($0.80)	$0.96–$1.92 ($1.31)	$0.60–$1.40 ($0.80)	$0.96–$1.92 ($1.31)
Interest on Animal	$14.65–$40.48 ($22.71)	$20.23–$55.90 ($31.36)	$12.74–$36.17 ($19.91)	$17.60–$49.95 ($27.49)
Spring/Summer Cost	**$116–$241 ($151)**	**$145–$289 ($195)**	**$113–$236 ($147)**	**$142–$284 ($192)**
Total Cost	**$292–$512 ($353)**	**$323–$560 ($398)**	**$257–$405 ($300)**	**$285–$452 ($344)**

[1]Costs are displayed as ranges between minimum and maximum values across years followed by the average in parentheses.

Table 2. Overview of the profitability ($/steer) of growing steers with two different rates of winter gain (2.0 or 0.8 lb/d, fast and slow, respectively) and three different marketing times, February, July, or September over an 18 year period from 1999 through 2017.

	Years Profitable	Average Net Profit	Maximum Net Profit	Minimum Net Profit
February Fast	10	$45.02	$211.53	-$80.57
February Slow	6	-$24.10	$126.63	-$195.43
July Fast	16	$123.03	$691.07	-$196.40
July Slow	16	$128.30	$634.67	-$211.06
September Fast	15	$142.83	$790.06	-$276.56
September Slow	13	$112.62	$719.93	-$312.26

The use of livestock risk protection and cattle futures contracts were also analyzed as a tool to mitigate risk for the September marketing date scenario. Data on Livestock Risk Protection (LRP) insurance was available for years after and including 2015, resulting in 3 years of usable data. Livestock Risk Protection was examined as a tool to mitigate risk at the highest level of protection offered in the data set. These coverage rates ranged from 97.63% to 99.18%. These data was gathered using the USDA's LRP Coverage Price, Rates and Actual Ending Values data set updated on 3/26/20 (United States Department of Agriculture, Washington, D.C.).

Results

An overview of the final net profit of the two winter growth rate scenarios with marketing in February, July, or September is shown in Table 2. The main driver in system profitability appeared to be the cattle market. Selling in February was determined to not be an effective marketing strategy as it was profitable much less frequently than selling in July or September. For both July and September, regardless of winter growth rate, the majority of years were profitable. The maximum profitability for these scenarios happened in the same year (2014) and the greatest losses occurred in the same year (2016). When evaluating the mean net profit, the fast winter growth combined with marketing in September appears to standout, netting on average $14.53/steer more than the next best scenario (July SLOW). However, the September FAST also had more risk as demonstrated by the spread from maximum to minimum profitability across years in comparison to July SLOW.

In order to visualize the relative variability in net profitability when using the two winter growth rates coupled with either July or September marketing, histograms were constructed (Figure 1). Figure 1A shows that a fast winter growth production method paired with a marketing date in September created more favorable results in comparison to it being paired with a marketing date in July. This is evidenced not only by a $19.80/steer higher average net profit for the September marketing date

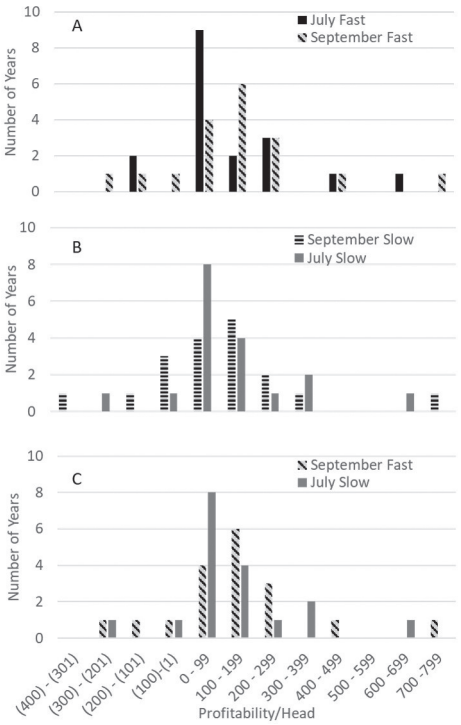

Figure 1.

over the 18-year analysis, but also an increased number of times net profits exceeded $100/steer. However, the fast September method also created one more year of net loss than marketing in July. In examination of the July FAST scenario, it significantly increased the number of years that generated a net profit between $0 and $99. However, this was outweighed by the fact that the September method generated four more occurrences where net profits were above $100. The September method also showed an instance where net profit was greater than $700, which the July method was unable to do. In summary, retaining the steers through September created slightly more risk but more instances of higher profit in the fast winter growth scenarios.

When examining the slow growth method paired with marketing dates in July and September (Figure 1B), it was found that net profits were shifted towards the negative when comparing September SLOW to July SLOW. The September SLOW scenario had three more instances of negative net profits and an average net profit $15.68/hd below the July SLOW scenario (Table 2). This is primarily because of the price slide. Steers in the slow winter growth scenarios were assumed to weigh an average of 915 lbs. in July and the average market price for that weight and time was $126.95/cwt. over the 18 years of data. In September, they were assumed to weigh an average of 1,005 lbs. and the average market price for that weight and time was $117.16/cwt. This is different than the fast winter growth scenarios where the average July weight and price were 1,010 lbs. and $118.96/cwt., respectively, while September weights were 1,076 lbs. and September prices averaged $117.16/cwt.

Finally, a comparison of the two best scenarios, September FAST and July SLOW, is shown in Figure 1C. While there is one more instance where the September FAST scenario results in a negative net profit, this is more than counterbalanced by three more instances where the September FAST scenario results in net returns above $100/hd.

By increasing the maximum profit that a producer is able to create and increasing the average net profit overall, it was found that utilizing a fast winter growth method combined with holding steers until September was the most profitable scenario for producers to utilize. In addition to this, it was found that producers who utilize slow winter growth will realize higher profits by marketing in July in comparison to September, and that marketing in July yields nearly the same average profitability no matter the winter growth method used.

The data was also analyzed using futures contracts as a marketing tool, and it was found that net profit was decreased by an average of $18/head when a futures contract was included each year. However, a futures contract position greatly reduced the amount of money lost during years where there were significant drops in livestock auction prices, as was the case in the fall of 2016. In 9 of the 18 years analyzed, net profits were increased by utilizing futures contracts, and 9 years where profits were decreased by utilizing futures contracts. Unfortunately, there were also not any predictive measures found in this study that might help producers decide when it is profitable to utilize futures contracts. This is evidence of market arbitrage principles that result in futures contract price offerings being the best predictor of futures contract settlement prices. It is important to note there were no years analyzed where using cattle futures contracts resulted in a net loss when a producer could have realized a net profit without using futures contracts. This analysis showed that futures contracts could be used to protect against cyclical patterns that seem to show low cattle auction prices coming directly after extreme high cattle auction prices but that protection comes at a cost of about $18/head with no great predictors as to when it is not needed.

Because of limitations in data available from the USDA on LRP insurance, only three years could be analyzed using LRP as a market price risk management tool. Of those years, the years 2016 and 2018 resulted in an indemnity payout to the producer. In 2016, this payout was enough to turn what would have been a net loss of $276.56/head without LRP insurance into a net loss of $105.72/head. In 2018, the indemnity payout was not enough to cover the entire cost of the LRP premium paid, and resulted in decreasing the net profit by $46.91/head, turning what would have been a net profit of $134.80/head without LRP insurance into a net profit of $87.89/head. In 2017, there was no indemnity payout, resulting in an added cost of $63.65/head for the producer to pay for the LRP premium. This added cost turned what would have been a net profit of $439.78/head without LRP insurance into a net profit of $376.13. Overall, by utilizing LRP insurance, a producer would have increased their average net profit over those three years by $20.09/head.

When using the production methods assumed in this study, the net profits were largely driven by cattle market prices. A driving factor in the results of this study is the higher weight that cattle achieve when using the fast winter growth method in comparison to the slow winter growth method. When utilizing the fast winter growth method, both the July and September cattle exceeded 1000 lbs in weight (1010 lbs in July and 1076 lbs in September) so they fell into the same CWT price category. This resulted in an average September market price that was only $1.80/CWT below the average July market price. However, the September cattle received a higher overall sale price per head due to the added 67 lbs of weight. Even though it costs

slightly more to retain the cattle on grass until September, the greater overall revenue outweighed the extra input costs of utilizing a marketing date in September.

Many producers in Nebraska have stated a belief that marketing cattle in July yields a greater price in comparison to September. Given the scenarios used in this study this was only partly true, in the case when utilizing slow winter growth. When utilizing the slow winter growth, it was more profitable to market in July as compared to September. The reason for this is that steers in the slow growth scenario cross the 1000 lbs threshold by being held until September, going from 915 lbs in July to 1005 lbs in September. This increase in weight decreases the average sale price per CWT by $11.14 as the animal changes weight categories, negating the reduced costs associated with the slow winter growth method, and ultimately decreasing overall net profits.

Another finding of this study is the most extreme high and low net profit years occurred in the same years across all four scenarios. The year 2014 was found to be a significantly higher year for net profits as market prices were high and holding value. The year 2016 was a significantly lower year for net profits as prices were trending down. Noticing these extreme high and low values, it was initially thought that there could be a potential for these data to provide a predictive value in determining when markets might be best suited for July or September selling to capitalize on the extreme highs and avoid extreme lows. However, this was not the case. Across almost all individual years, it nearly always worked best for producers to hold cattle until September and utilize fast winter growth. Even Livestock Risk Protection insurance predicted prices were not very good indicators of future prices. While they were quite accurate on average over a number of years, in a specific year the predicted price could be as much as 25% higher or lower than the actual price turned out to be.

The results of this study also indicate that the use of Livestock Risk Protection can help mitigate risk for producers who are not financially able to take the kinds of major losses that can occur in years such as 2016. However, although the analysis showed that producers would realize an increase in net profit over the three years use of LRP was examined, this may be somewhat misleading due to the small number of years studied and the significant indemnity paid out in 2016. Therefore, producers who are financially stable enough to incur major losses in a single year and still be able to operate in the following year may not need to use LRP, as doing so might decrease the average net profit of the operation in the long run. A similar statement can be made about using cattle futures as a marketing tool to protect against risk. While it will decrease the average net profit of an operation over a number of years, it does have the ability to protect against particularly bad years where major losses occur.

Implications

Overall, this study indicates that wintering practices for retained calves and summer grazing plans need to be considered together. A fast winter growth scenario coupled with summer grazing through September resulted in the highest average profit among the four scenarios studied. If a slow winter growth practice is utilized, there is a financial incentive to market the calves off grass in July to avoid potential price slide impacts in late summer as the calves transition from below 1,000 pounds to above 1,000 pounds per head. Fast winter growth practices diminish this risk and increase the incentive to retain the calves through September to yield the highest net profit.

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Alternative Heifer Development Systems Utilizing Corn Residue and Cover Crops

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Summary with Implications

Growth and reproductive performance of heifers developed in 3 different winter systems to target a common body weight by 10.5 months of age was evaluated. Systems were corn residue grazing supplemented with dried distillers grains, corn residue supplemented with wheat midds, or cover crop followed by corn residue grazing supplemented with dried distillers grains. Heifers were on their respective treatment from 7 to 10.5 months of age (approximately 98 days) and then comingled and fed a common diet. Overall gains were greatest for heifers grazing cover crops compared to heifers on corn residue treatments. Prebreeding body weight was ~20 pounds greater for heifers grazing cover crops compared to other treatments. Pregnancy rates were greater for heifers on cover crop (75.4%) compared to heifers supplemented with wheat midds (64.3%), while heifers supplemented dried distillers grains (69.5%), were intermediate not differing from cover crop or wheat midds. These data suggest that plane of nutrition during the development period may have affected fertility. Utilizing oat-brassica cover crop grazing during early winter to achieve a high rate of gain followed by corn residue grazing with dried distillers grains supplementation to target a lower rate of gain could be effective for developing beef heifers.

Introduction

Plane of nutrition at certain times during development may affect oocyte quality as well as attainment of puberty. In particular, a nutritional challenge may negatively impact oocyte growth, resulting in reduced fertility when oocytes are later ovulated. Corn residue grazing alongside dried distillers grains (DDGS)-based supplementation can serve as a low-cost option for wintering growing cattle and developing beef heifers. Additionally, supplementation levels of DDGS can be manipulated to target different rates of gain. Dried distillers grains with solubles is commonly supplemented in corn residue grazing systems because it serves as both a good protein and energy source. In other parts of the Midwest, wheat midds could serve as a viable supplement option as they are a good source of protein and moderate in energy content. Grazing of late-summer planted oat-brassica cover crops can also be an effective way to winter growing cattle (*2017 Nebraska Beef Cattle Report*, pp. 40–42); however, this option has not yet been evaluated for heifer development. The objective of this study was to evaluate growth, development, and reproductive performance of heifers developed in 3 different winter systems targeted to result in a common BW at 10.5 months of age.

Table 1. Supplement intakes of heifers during mid-November to mid-January (Phase 1) and mid-January to late February (Phase 2) of the winter grazing period.

	Treatment[1]		
	CD	CW	CC
Supplement DM intake, lb/hd/d			
Phase 1[2]	1.61	3.57	-
Phase 2[3]	2.16	4.32	0.76

[1]Grazing treatments: corn residue with DDGS supplementation (CD); corn residue with wheat midds supplementation (CW); late summer planted cover crop followed by corn residue with DDGS supplementation (CC).

[2]Heifers 9 months of age at the end of phase.

[3]Heifers 10.5 months of age at the end of phase.

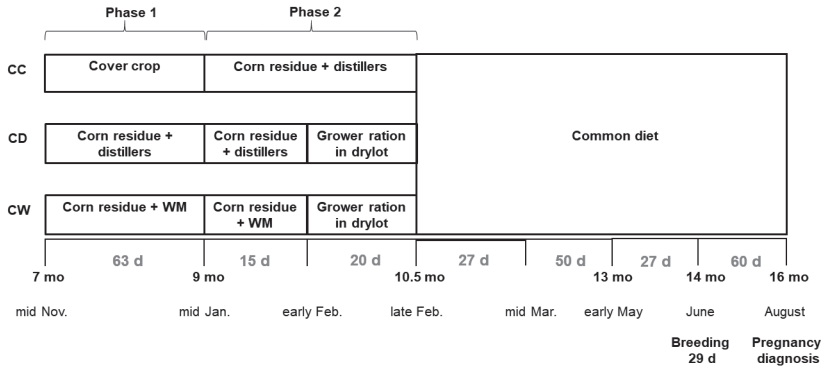

Figure 1. Experimental timeline and illustration of dietary treatments of winter heifer development systems, with heifer age indicated at hash marks. Heifers were assigned to either graze cover crop followed by corn residue grazing (CC) or graze corn residue while receiving protein supplementation as either dried distillers grains (CD) or wheat midds (CW). At the end of Phase 1, CC heifers were placed on corn residue and received a DDGS supplement for the remainder of the experimental feeding period (Phase 2). In phase 2, CD and CW heifers remained on corn residue for 15 d before being placed in the drylot. Following Phase 2, all heifers were comingled and fed a common diet. Breeding season began in June and lasted for 29 d; pregnancy diagnosis occurred in August.

Table 2. Dietary composition by year of grower ration fed during drylot period for heifers grazing corn residue with DDGS (CD) or wheat midds (CW) supplementation.

	Year		
Ingredient, % of DM	2016	2017	2018
Alfalfa haylage	46.7	17.5	-
Earlage	38.9	40.0	-
Corn silage	-	42.5	-
Alfalfa hay	14.4	-	-
Alfalfa/grass hay	-	-	74.0
Corn, dry-rolled	-	-	26.0
Diet nutrient content, % of DM			
CP	15.4	10.3	13.0
TDN	70.2	73.5	64.5

Table 3. Effect of winter heifer development system on bodyweight and average daily gain of heifers.

	Treatment[1]				
Item	CC	CD	CW	SEM[2]	*P*-value
Mid-November (Initial) BW, lb	483	481	478	2.34	0.34
Mid-January (Mid) BW, lb[3]	589[a]	562[b]	547[b]	5.45	<0.01
Late-February (Final) BW, lb[4]	619[a]	595[b]	584[b]	6.44	<0.01
May (Prebreeding) BW, lb[5]	701[a]	679[b]	677[b]	5.89	<0.01
May BW, % of mature BW[6]	52[a]	50[b]	50[b]	0.44	<0.01
ADG, lb/d					
Mid-November to mid-January (Phase 1)	1.68[a]	1.28[b]	1.08[b]	0.09	<0.01
Mid-January to late February (Phase 2)	0.79[a]	0.90[ab]	1.08[b]	0.07	<0.01
Early February to late February (Drylot)[7]	–	1.46	1.51	0.17	0.77
Late February to May (Prebreeding)	1.01	1.15	1.17	0.07	0.10
Mid-November to late February (Overall)	1.39[a]	1.17[b]	1.10[b]	0.07	<0.01

[a,b]Means within a row lacking a common superscript differ ($P < 0.05$).

[1]Grazing cover crop followed by grazing corn residue with DDGS supplementation (CC); grazing corn residue with DDGS (CD) or wheat midds (CW) supplementation followed by grower ration in the drylot.

[2]Average SEM across all treatments.

[3]CC to corn residue and receiving DDGS supplementation; CD and CW on corn residue receiving DDGS and wheat midds supplementation, respectively, for 15 days.

[4]CC removed from corn residue; CD and CW removed from drylot.

[5]Measured 27 d before breeding on June 1.

[6]Based on herd average mature cow BW of 1350 lb.

[7]20 days.

Procedure

A total of 1,012 spring-born heifers were used in a 3-year study conducted from 2016 to 2018 at the U.S. Meat Animal Research Center. Heifers were weaned at 148 ± 17 d of age, and each year heifers were classified by birthdate and weaning weight and randomly assigned within classification to one of 12 replicates. Four replicates were randomly assigned to one of 3 grazing treatments: corn residue with DDGS (CD) or wheat midds (CW) supplementation, or late summer planted oat-brassica cover crop followed by corn residue supplemented with DDGS (CC). All heifers received a mineral supplement while on their respective grazing treatments. The cover crop was planted in August and consisted of a mixture of oats (84 lb/acre), daikon radish (2 lb/acre), and purple top turnip (1.5 lb/acre). Supplementation was provided 3 times weekly to achieve 45% of mature BW (607 lb) by 10.5 months of age, and heifers were targeted to achieve 55% of mature BW (744 lb) by breeding in June. Average daily supplement intakes for each treatment are listed in Table 1.

A timeline of the study is provided in Figure 1. Grazing treatments were initiated in mid-November of each year. After 63 d (end of Phase 1/start of Phase 2), heifers on CC treatment were moved in mid-January to corn residue and supplemented with DDGS for the remaining 35 d of the winter treatment period. Heifers on CD and CW treatments remained on corn residue until d 78 and were subsequently moved to the drylot in early February where they received a grower ration for the last 20 d of the treatment period (Table 2). Relocation of CD and CW heifers to the drylot at this time occurred because weather conditions in Year 1 resulted in low corn residue availability; CD and CW heifers were managed as such in Year 2 and 3 to be consistent across years. Heifers in the drylot consumed 11.2 lb DM/d and were targeted to gain 1.1 lb/d. The treatment period ended after 98 d in late February (end of Phase 2) at which point all heifers were comingled and fed a common diet. Heifers (14 mo of age) were bred via natural service for a 29-d breeding season that started in June.

Individual body weights were collected on all heifers at study initiation in mid-November (d 0), end of Phase 1 (d 63), end of Phase 2 (d 98), and the first week of May. In mid-March, heifers were ultrasounded to determine reproductive tract score (RTS). The use of RTS is a practical on-farm method to determine heifer pubertal status. Reproductive tract scoring is based on a range of 1 to 5, with 1 being an infantile tract and no palpable follicles, and 5 being a tract with a functioning corpus luteum (CL) present (i.e., heifer is cycling). In early May at 13 months of age, RTS was again evaluated, and follicle count, ovarian length and height, and uterine horn diameter was determined via ultrasound. Hip heights

Table 4. Effect of winter heifer development systems utilizing corn residue and cover crop on reproductive measures and pregnancy rate.

	Treatment[1]				
Item	CC	CD	CW	SEM[2]	*P*-value
March					
Tract score[3]	4.18[a]	4.07[b]	4.09[b]	0.03	0.04
May					
Tract score[3]	4.61	4.50	4.56	0.03	0.08
Uterine horn diameter, mm	10.7	10.8	10.7	0.10	0.58
Total follicle count[4]	20.7	21.3	20.6	0.49	0.55
Average ovary length, mm	24.4	24.4	24.2	0.21	0.82
Average ovary height, mm	14.0	13.9	14.1	0.11	0.43
Hip height, in	48.6	48.4	48.3	0.11	0.09
BCS[5]	5.4	5.3	5.3	0.03	0.10
August					
Pregnancy rate, %	75.4[a]	69.5[ab]	64.3[b]	0.03	0.03

[a,b]Means within a row lacking a common superscript differ ($P < 0.05$).

[1]Grazing cover crop followed by grazing corn residue with DDGS supplementation (CC); grazing corn residue with DDGS (CD) or wheat midds (CW) supplementation followed by growing ration in the drylot.

[2]Average SEM across all treatments.

[3]Reproductive tract score (1 = prepubertal to 5 = pubertal).

[4]Sum of follicles present in left and right uterine horns.

[5]Body condition score (1 = emaciated to 9 = obese).

and body condition scores (BCS) were also collected at this time. Heifers were rectally palpated in August to diagnosis pregnancy.

All data except for pregnancy data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N. C.). Pregnancy data were analyzed using the GLIMMIX procedure of SAS with binomial distribution of the data. Fixed effects were treatment and year, and replicate within a year was a random effect. Kenward-Roger approximation was utilized for degrees of freedom. Significance was declared at $P \leq 0.05$.

Results

Heifer body weight and average daily gain

Initial (mid-November) BW did not differ among treatments ($P = 0.34$; Table 3). At the end of Phase 1 (mid-January), CC had a greater BW (589 lb) than CD and CW (562 and 547 lb; respectively); CD and CW did not differ from each other ($P < 0.01$). Final (late-February) BW was greater for CC than for CD and CW ($P < 0.01$), with CC being approximately 25 lb heavier than CD and 35 lb heavier than CW. In May (prebreeding), BW was 20 to 25 lb greater for CC (701 lb) compared to CD (679 lb) or CW (677 lb; $P < 0.01$). Consequently, CC heifers achieved a greater percentage (52%) of mature BW in May (27 d prior to the breeding season) than CD and CW heifers (50%; $P < 0.01$).

Average daily gain during Phase 1 was greater for CC than for CD and CW (1.68 vs. 1.28 and 1.08 lb/d, respectively; $P < 0.01$). In Phase 2, CW had an ADG of 0.29 lb/d more than CC, but ADG was not different from CD ($P < 0.01$). During the 20-d period in the drylot, ADG was not different between CD and CW ($P = 0.77$) as both gained approximately 1.50 lb/d. Average daily gain over the entire winter treatment period for CC was 0.22 lb/d greater than CD and 0.29 lb/d greater than CW, whereas CD and CW did not differ from each other ($P < 0.01$).

Reproductive measures

Heifer reproductive measures are listed in Table 4. In March, CC had a greater RTS than CD and CW heifers ($P = 0.04$); however, there were no differences in RTS across treatments in May ($P = 0.08$), suggesting that all heifers were of similar reproductive maturity prior to the breeding season. Within CC, CD, and CW treatments, the percentage of heifers with an RTS of 5 (i.e., cycling) by May were 65, 57, and 59%, respectively ($P = 0.24$). No differences were observed across treatments for uterine horn diameter, total follicle count, ovary length, or ovary height ($P \geq 0.43$). Hip height and BCS were also not different across treatments ($P \geq 0.09$). Pregnancy rates in August were greater in CC heifers (75.4%) compared to CW heifers (64.3%) but were not different from CD heifers (69.5%; $P = 0.03$).

Conclusions

Despite different rates of gain throughout the treatment period, all groups were similar in reproductive maturity by breeding. Therefore, it is concluded that plane of nutrition of heifers from 7 to 10 months of age may have an effect on reproductive success at the time of breeding. Achieving greater rates of gain with oat-brassica cover crop grazing from 7 to 9 months of age followed by corn residue grazing with DDGS supplementation for lower rates of gain could potentially be an effective method for developing beef heifers.

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Impact of Biochar Supplementation in Growing Diets on Greenhouse Gas Emissions

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Summary with Implications

A study was conducted to evaluate the impact of feeding biochar growing diets on cattle performance and methane and carbon dioxide emissions. Two treatments were evaluated, a forage-based control diet without biochar and a diet with biochar included at 0.8% of the diet dry matter, replacing fine ground corn in the supplement. Pens of cattle were rotated through a two-sided emissions barn (2 pens evaluated simultaneously) to capture CH_4 and CO_2 production. There were no statistical differences in performance or gas emissions for steers fed a biochar supplemented diet compared to control. Numerically, biochar supplemented steers had a 2.9% improvement in feed conversion and 3.4% increase in gas emissions compared to control steers.

Introduction

Biochar, a carbonized charcoal, has recently gained popularity in livestock feeding as a potential feed supplementation to reduce greenhouse gas (GHG) emissions. Cattle feeders have demonstrated interest in including biochar as part of the feeding regimen, but the broad characterization of the product and its varying attributes create a barrier for commercial feedlot application. The inclusion of biochar in cattle diets has been suggested to reduce GHG production, primarily in the form of methane (CH_4). Methane is a potent GHG and is of environmental concern. Enteric emission of CH_4 represents an energetic loss in cattle as well, estimated between 2 to 12% of total energy intake. When included in the diet, there are several theories on mode of action. Biochar may act as carbon sink, adsorb methane, or impact microbial community in the rumen, resulting in reduced methane produced during rumination and eructation. The objective of this study was to quantify the impact of biochar supplementation on overall performance and carbon dioxide (CO_2) and CH_4 emissions of growing steers.

It is important to note that biochar is not currently approved by the FDA to be fed to cattle intended for human consumption. While these cattle were not harvested at the end of this growing trial, a food use authorization from the FDA was obtained before the start of the trial.

Table 1. Diet composition for steers fed a grower diet with or without biochar inclusion (DM basis)

Ingredient, %	Biochar	Control
Wheat Straw	40	40
Corn Silage	40	40
MDGS[1]	15	15
Supplement[2]	4.2	5
Biochar[3]	0.8	0

[1]MDGS= Modified distillers grains plus solubles

[2]Formulated to provide 0.3% salt, 1% urea, 1.31% limestone, 0.125% tallow, beef trace mineral, vitamin A-D-E, and 200 mg/d monensin (Rumensin, Elanco Animal Health, Greenfield, IN) as % of diet DM, utilizing fine ground corn as the carrier

[3]Biochar was added as an ingredient to the feed truck and replaced fine ground corn inclusion in the supplement

Procedure

A 77-day feedlot growing study was conducted at the University of Nebraska-Lincoln Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE. Yearling steers (n=160; initial BW=788 lb) were assigned to two treatments (Table 1); a negative control grower diet (no biochar inclusion) and grower diet with 0.8% biochar inclusion. Diets were identical other than biochar inclusion, and contained wheat straw, corn silage, and modified distillers grains plus solubles.

Pens were assigned randomly to treatment (8 pens/treatment) and steers were stratified into 3 BW blocks and assigned randomly to pen (10hd/pen). Before trial initiation, steers were limit-fed a common diet of 50% alfalfa hay and 50% Sweet Bran (Cargill, Blair, NE) offered at 2% of BW. Steers were weighed in the morning of day 0 and 1 of trial and weights were averaged to establish initial BW. Steers were implanted with Revalor-IS (200mg trenbalone acetate + 40mg estradiol; Merck Animal Health, Summit, NJ) on day 1 of study.

Biochar was provided by High Plains Biochar (Laramie, WY), and was sourced from forest wood waste, primarily ponderosa pine trees. Dry matter of the biochar fluctuated with moisture in the air from 57% to 76% DM with an average of 70%. On a DM basis, carbon (C) content of the biochar was 82.8%, with a surface area of 426 m^2/g, bulk density of 6.73 lb/ft^3, and pH of 9.49. Biochar particle size ranged from < 0.5-mm to 8-mm, approximately 66% of biochar sampled sizing <2-mm and 1% of biochar sampled ≥4-mm.

The UNL ENREC emission barn, equipped with a negative pressure system to monitor and record CH_4 and CO_2 production, was utilized for 8 consecutive weeks to monitor emissions from growing steers. The emission barn has 2 isolated pens (no emission cross-over) and operates using two air sensors, the LI-COR 7500 and LI-COR 7700 (LI-COR, Lincoln, NE) to monitor CO_2 and CH_4, respectively. Eight pens of cattle, 4 control and 4 biochar, were randomized to rotate through the methane barn by pairing replications

Table 2. Effect of biochar supplementation to growing steers on performance and gas emissions

	Treatments			
	Biochar	Control	SEM	*P*-value
Performance				
Initial BW, lb	800	800	2.0	0.96
Ending BW, lb	1055	1051	4.5	0.50
DMI, lb/d	18.6	18.9	0.17	0.23
ADG, lb	3.24	3.19	0.050	0.46
F:G[1]	5.71	5.88	—	0.25
Emissions daily				
CH_4, g/steer	203.8	196.2	6.62	0.45
CO_2, g/steer	5982	5725	143.1	0.25
CH_4, g/lb of DMI	9.5	9.3	0.30	0.60
CO_2, g/lb of DMI	263.7	254.6	4.90	0.24

[1]Analyzed as G:F, the reciprocal of F:G

within BW block (1 rep per treatment). Pairings were rotated through the barn for two 5-d periods, with each treatment represented in the barn concurrently. Each week, steers entered the barn Wednesday morning and remained in the barn until Monday morning when they were returned back to their feedlot pen. Manure CO_2 and CH_4 emissions were calculated from the remainder of Monday, when cattle were absent from barn. The barns were scraped clean each Tuesday to develop a baseline emission level post manure removal. Baseline emission levels of CO_2 and CH_4 were subtracted from manure emission levels of CO_2 and CH_4 and final values were divided over 5 days and 10 head, to account for individual animal emissions. Following these steps, an average CO_2 value of 16.89 g per steer and CH_4 value of 0.08 g per steer were subtracted from the daily emission total for CO_2 and CH_4.

Performance and emissions data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. For performance data, BW block was included as a fixed effect. For emissions data, day was a repeated measure. Six days (out of 40 total) were not usable due to complications with barn sensor recording. Concentrations of CO_2 and CH_4 reached above 60 ppm at certain points throughout the day, these concentrations are greater than what has been reported in previous literature. High concentrations of CO_2 and CH_4 in this study were due to housing 10 head/pen in the barn and the high inclusion of low quality forage in the diet.

Results

Results from this study show no statistical difference in performance outcomes between biochar supplemented steers and control ($P \geq 0.23$; Table 2). Numerically, average daily gain (ADG) was greater ($P = 0.46$) and dry matter intake (DMI) was lower ($P = 0.23$) for biochar supplemented cattle. This led to a 2.9% improvement in feed conversion for biochar supplemented steers, that was not statistically significant ($P = 0.25$). Although 8 replicates were analyzed per treatment, the limitation of studying only two treatments leads to insufficient statistical power, and F:G response should be further evaluated to determine repeatability.

Emissions of CO_2 and CH_4 did not statistically differ between steers fed biochar and control treatments ($P \geq 0.24$). Carbon dioxide and methane emissions were numerically lower for control steers compared to biochar supplemented steers when reported as g per day (4.0% lower) or g per lb of DMI (2.8% lower). Based on results from this study, there was no indication that feeding biochar reduces methane emissions in growing steers, especially when considering numerically lower DMI, which measured 18.6 lb/d for biochar supplemented cattle compared to 18.9 lb/d for control.

Recent work evaluating biochar fed to cattle has had mixed results. One study completed in Southeast Asia reported a 24% reduction in CH_4 emissions from cattle, while a study completed in Canada found no differences in CO_2 or CH_4 emissions. Previous work evaluated biochar supplemented to cattle at 0.8 and 3.0% of diet and measured emissions using headbox technology, reporting a decrease in CH_4 emissions for cattle supplemented biochar at these dietary concentrations (*2019 Nebraska Beef Cattle Report*, pp. 56–59). Type of diet, physical properties of the biochar, and inclusion percentage of biochar in the diet are all potential reasons for differing results.

In conclusion, biochar of this characterization supplemented at 0.8% of diet in growing steers does not have a significant impact on GHG emission reduction when compared to negative control.

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Growing Calf Intake of Hay or Crop Residue Based Diets

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Summary with Implications

It is important to know or predict feed intake by growing calves on forage-based diets in order to balance these diets for nutrients such as energy and protein. Several growing calf studies with forage-based diets were summarized. These studies evaluated the use of crop residue as a substitute for conventional forages, primarily grass hay. Calves gained about 1.8 lb/day for all forage-based diets. Calves consumed 2.6% of body weight daily when fed hay-based diets, but those fed residue with distillers grains diets consumed only 1.6% of body weight. However, when feeding the residue with distillers grains diets, the cost per lb of gain was less than the grass hay based diets.

Introduction

Most of the feed used in beef production is forage. The amount of forage intake is very important because the energy content is often relatively low. Also, it is essential to know feed intake of the calves in order to balance the diet for energy, protein, etc. There are 2 mechanisms that are proposed to control forage intake, both relating to rumen fill. Fill is the amount of forage the animal can physically contain. The first mechanism proposed is physical rumen fill limits the amount of fiber (neutral detergent fiber, NDF) that cattle can consume from 1.35% to 1.70% of body weight daily. The other mechanism is that the capacity to consume, ruminate and pass forage through the digestive tract is related to fecal dry matter production. Clearly, the more digestible the forage, the less feces produced and the more the animal would consume. The maximum fecal excretion (FE) is proposed to be between 1.07 and 1.16% of body weight daily. Those data relate to conventional forages, primarily grass hays. Because crop residues are readily available, it is important to know how well they compare with conventional forages. The objective was to compare intakes of steers consuming crop residues with distillers grains to those consuming conventional forage-based diets.

Table 1. Ingredient nutrient composition

Ingredients	TDN[1]	DMD[2]	NDF[3]	CP[4]
Grass Hay, %	52	52	71	7.1
Alfalfa Hay, %	55	55	63	16
Sorghum Silage, %	67	67	59	8.6
Corn, %	83	83	0	9.0
Soybean meal, %	80	80	0	50
Crop residue, %	43	43	80	3.5
Distillers grains, %	108	80	35	31
Supp[5], %	80	80	0	0
Sweet Bran, %	89	80	40	23

[1] Total digestible nutrients
[2] Dry matter digestibility
[3] Neutral detergent fiber
[4] Crude protein
[5] Supplement providing minerals and vitamins

Procedure

Numerous experiments have been conducted at ENREC using similar protocols. Studies used steers, and the studies selected were initiated 3 to 5 months following weaning. Calves were limit-fed for 3 to 5 days followed by 2 to 3 day initial and ending body weights. Some of the studies involved calves (8 to 12 hd per treatment) being individually fed using the Calan gate system. Other studies involved pen-fed calves with 8 to 12 hd per pen and 6 to 10 pens per treatment. Seventy-seven treatment means were developed overall, but only a limited number are summarized here. Individually fed, 11 month old implanted steers fed conventional forages, crop residues with distillers grains (DG), or hay with DG within a similar range of daily gains were summarized. Feeds were sampled weekly for dry matter and laboratory analysis. This allowed for the calculation of FE as: Dry Matter Intake—(Dry Matter Intake × Dry Matter Digestibility). Table 1 shows the digestibility and ingredient composition that was calculated from metabolism studies that were done in conjunction with the feeding trials. Cattle were fed ad libitum in all studies.

Diets from these studies were assigned to 1 of 3 categories: Hay (hay based diet with some grain and protein supplement), Residue DG (crop residue based diet with distillers grains supplementation), and Hay DG (hay based diet with distillers grains supplementation). The conventional Hay diets contained alfalfa hay and sorghum silage. A simplified diet of grass hay, corn and soybean meal (SBM) was formulated to provide the energy and protein of the alfalfa hay and silage diet (Table 2).

Results

Composition of the diets and cattle performance are shown in Table 2. The alfalfa hay and sorghum silage diet is 95% (DM basis) forage. Steers consumed 2.68% of

Table 2. Diet composition and calf performance

	Diet Type				
	Hay[1]	Hay[2]	Residue DG[3]	Residue DG[4]	Hay DG[5]
Ingredients, % of diet DM					
Grass Hay, %	-	60	-	-	78
Alfalfa Hay, %	57	-	-	-	-
Sorghum Silage, %	38	-	-	-	-
Corn, %	3	29.7	-	3	-
Soybean meal, %	-	8.3	-	-	-
Crop residue, %	-	-	63	55	-
Distillers grains, %	-	-	35	40	20
Supp[6], %	2	2	2	2	2
Cattle performance					
Average BW, lb	745	745	755	737	705
Dry matter intake, % of BW	2.68	2.68	1.64	1.55	2.51
Average daily gain, lb/day	2.0	2.0	1.71	1.87	1.90

[1]Forage Diet based on alfalfa hay and sorghum silage

[2]Grass hay, corn and soybean meal calculated to supply energy and protein equal to alfalfa hay and sorghum silage diet

[3]Corn or wheat residue plus distillers grains, average of 7 treatment means in 4 studies

[4]Corn stalks plus distillers grains treatment from same study as alfalfa and sorghum silage treatment

[5]Grass hay plus distillers grains, 1 treatment

[6]Supplement providing minerals and vitamins

Table 3. Intake regulation

	Diet Type[1]				
	Hay	Hay	Residue DG	Residue DG	Hay DG
DMI[2], % BW	2.68	2.68	1.64	1.55	2.51
NDFI[3], % BW	1.43	1.14	0.79 (0.97)	0.61 (0.90)	1.37 (1.50)
FE[4], % BW	0.95	0.95	0.68	0.62	1.07

[1]See Table 1

[2]Dry matter intake

[3]Neutral detergent fiber intake, dry matter basis, values without parenthesis represent NDFI without NDF from DG included and values in parenthesis represent NDFI with NDF from DG included

[4]Fecal excretion, dry matter basis

body weight as dry matter daily and gained 2 lb/day. The second hay diet was formulated to provide equal energy and protein to the first hay diet using grass hay, corn and soybean meal. Only one trial is available with a 66% hay diet supplemented with corn and protein supplement. However, the trial involved nonimplanted, 8 month old heifers. Their intake was 2.52% of body weight and a 6% increase from implanting would result in intake of 2.67% of body weight, which is consistent with the formulated hay diet.

The first residue DG diet is a summary of 7 treatment means from 4 studies. Distillers grains averaged 35% of the diet and the remainder was corn stalks and 2% supplement. Daily gain was somewhat less (86% of hay diet) than the hay diet, but intake was only 61% that of the hay diet. The second residue DG diet represents steers fed corn stalks and DG in the same study as those in the alfalfa hay and sorghum silage study. In this direct comparison, intake of the residue DG diet was only 58% of the hay diet.

A hay DG diet with 20% DG and 78% grass hay (DM basis) resulted in intakes and gains slightly less than the alfalfa and sorghum silage diet.

The two biological mechanisms that are proposed to limit intake are rumen fill and FE. Table 3 shows the intake of NDF and FE of the 5 diets. Neutral detergent fiber intake was calculated with and without the inclusion of the NDF from DG in all diets containing DG. Both NDF intake and FE were lower for the Residue DG diets, suggesting that fill is not the limiting factor for intake of the residue diets. Because the NDF content of residue is high (80% or greater), it could have been expected that fill would be the limiting factor for intake of the residue diets.

Because fill does not appear to be the answer, perhaps there are 2 other explanations for the lower dry matter intake. One is that the calves find the residues to be unpalatable. The other explanation is more complex. The cattle must reduce forage particle size from 20+ mm to 1 mm in order for the particle to pass from the rumen into and through the rest of the digestive tract. This reduction starts with chewing during consumption and follows with rumination. With conventional forages, reduced FE suggests some other intake control, such as energy value of the feed. However, it is possible that the reduced FE is a sign that particle reduction and passage is slower with residues than conventional forages.

In the 1980's, research was conducted with stalklage harvested with a John Deere stalker head immediately after high moisture corn harvest. This corn residue had less NDF (70%) compared to baled stalks (80%), more soluble carbohydrates and sufficient moisture to ensile. This corn residue was fed at 84% of the diet dry matter with a soybean meal supplement. Intake was 2.0% of body weight, NDF intake was 1.2% of body weight and fecal excretion was 0.92% of body weight. These values are greater than those of baled stalks with 35% DG and more similar to brome hay values of dry matter intake at 2.1% of body weight, NDF intake of 1.4% of body weight and fecal excretion at 0.95% of body weight. Palatability is probably the primary issue with low intake of baled stalks.

While overall intake was lower for the Residue DG diets, the diets contained 35% DG which have 130+% the energy of corn in forage-based diets. Further, the DG are an excellent supply of protein. Based on the performance data, a simple economic analysis was conducted using corn priced at $3.45/bu and other ingredients at comparable prices (Table 4). The cost per lb

Table 4. Economics

	Diet Type[1]				
	Hay	Hay	Residue DG	Residue DG	Hay DG
Dry matter intake, lb/d	19.9	19.9	12.4	11.4	17.7
Cost[2], $/lb DM	0.0622	0.0753	0.0515	0.0531	0.0623
Daily Feed Cost, $/animal	1.24	1.50	0.71	0.61	1.10
Cost, $/lb BW gain	0.62	0.75	0.42	0.32	0.58

[1]See Table 1

[2]Corn, $3.45/bu = $0.073/lb DM

Alfalfa hay $90/ton + $15/ton grinding = $0.06/lb DM

Sorghum silage = $0.06/lb DM

Grass hay, $85/ton + $15/ton grinding = $0.056/lb DM

Corn Stalks, $45/ton + $15/ton grinding = $0.034/lb DM

Soybean meal, $360/ton = $0.20/lb DM

Distillers grains, $0.073/lb DM (equal to corn)

Supplement, $300/ton = $0.15/lb DM

of dry matter is less for the Residue DG diet because of the lower cost of residues compared to hay. The lower intake and the lower diet cost per lb makes the daily cost of the Residue DG diet much less than both the Hay-based diet and the Hay DG diet. Feed cost of gain is also lower for the residue-based diets.

One of the 7 treatment means for the residue DG diets consisted of Sweet Bran and Soypass instead of DG, which provided similar performance to the distillers grains. The Soypass supplied undegradable protein that is provided by DG. These results suggest that a mixture of DG, as a source of rumen undegradable protein, and gluten feed would provide similar performance as DG alone.

Clearly, harvested cornstalks or wheat straw are not well consumed by steer calves and the same may be true for cows. With harvested corn residue, much of the residue is stalks or cobs which may be the primary unpalatable fractions. Alternatively, when corn stalks are grazed, the primary components consumed are husks and leaves. Because the leaves and husks are preferentially consumed, palatability must be better than for the stalks or cobs. Because we cannot harvest the husks and leaves separate from the stalks and cobs, we do not have direct measurements of intake of the husks and leaves. Based on cow performance while grazing corn residue and knowing the quality of the leaves and husks, we estimate that cow consumption of leaves and husks, even without supplement would be 2% of body weight (*2019 Nebraska Beef Cattle Report*, pp. 50–52).

In a recent study, cows were offered baled cornstalks in round bale feeders. The bales contained over 40% stems and cobs, the remaining nearly 60% was leaves and husks. The wasted and refused feed was measured and totaled to about 40%. Therefore, it appears the cows selected the leaves and husks and refused the stems and cobs. This is consistent with the grazing situation and suggests again that palatability is the issue with intakes of calves fed the ground residue, which minimizes the opportunity to sort stems and cobs.

Clearly the best use of corn residue is with grazing cows or calves because they select the more digestible and palatable parts leaving the less digestible and less palatable parts for soil cover. However, harvested cornstalks and wheat straw can be used economically in growing diets when fed with DG. Residues at 5% of finishing diets are likely very effective because the residues may be quite palatable to the cattle as a "roughage" in that feeding situation.

Conclusion

Intake of diets based on crop residues is about 30% less than intake of hay-based diets for growing steers. However, because the residues are less expensive and give similar performance when fed with DG, they are much more cost effective than hay-based diets.

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Evaluation of Models Used to Predict Dry Matter Intake in Forage-Based Diets

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Summary with Implications

Accurately predicting intake is critical to model performance of cattle in order to formulate diets to meet nutritional requirements. Modeling systems must be accurate in order to provide correct information to producers. Multiple studies with growing cattle consuming forage-based diets were summarized. Actual gain and weights of the cattle were used to determine predicted dry matter intake using the Beef Cattle Nutrient Requirements Model (2016). The predicted dry matter intakes were compared to observed dry matter intakes to determine accuracy of the prediction model. The model over predicted intakes at low TDN and under predicted intakes at higher TDN values, with the interaction at approximately 64% TDN. The Beef Cattle Nutrient Requirements Model (2016) does not accurately predict dry matter intake of growing calves consuming forage-based diets.

Introduction

Forage-based diets are primarily fed to calves to promote growth rather than fat deposition, which allows for greater carcass weights without becoming overly fat during finishing. The challenge to using forage-based diets is being able to provide adequate energy, protein, and minerals to meet the growth requirements of these calves. In order to meet these requirements, it is essential to predict dry matter intake (DMI). The concept of modeling is to use previous data to create a tool that can predict DMI, protein and energy requirements, and performance of growing cattle. Models can then be used in diet formulation to ensure optimal performance of the calves. There are different modeling tools that are currently available for use, but the most common is the Beef Cattle Nutrient Requirements Model (BCNRM) (2016). This is the newest version of what has commonly been referred to as the National Research Council (NRC) model. Our hypothesis was that the data used to build the current modeling system was based primarily on studies that were high-energy growing diets or finishing diets, and these data were extrapolated to fit high-forage, low-energy diets. Thus, the objective was to evaluate the current modeling tool's ability to predict DMI in high-forage, low-energy diets.

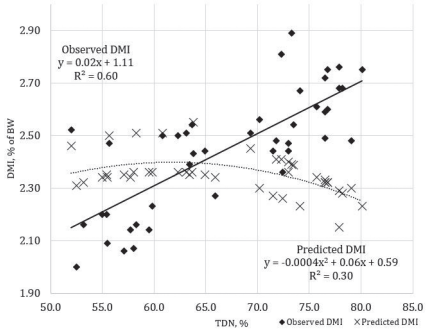

Figure 1. Observed versus predicted dry matter intake. Plot of observed (43 treatment means) and BCNRM (2016) predicted dry matter intake for forage based diets (hay or corn silage based with and without distillers grains) with TDN of 52 to 80%.

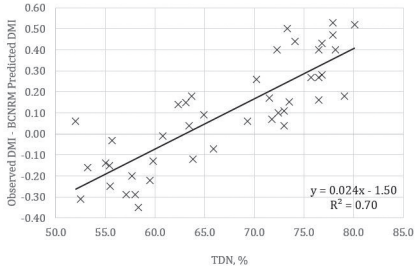

Figure 2. Difference between Observed and Predicted DMI relative to TDN. Plot of observed (43 treatments means) dry matter intake minus BCNRM (2016) predicted dry matter intake for forage-based diets (hay or corn silage based with or without distillers grains) with TDN of 52 to 80%

Procedure

Experiments used were conducted at the Eastern Nebraska Research and Extension Center, near Mead, NE, utilizing similar protocols. Studies included calves (8 to 12 hd per treatment mean) that were individually fed using the Calan gate system, or calves that were pen-fed with 8 to 12 head per pen and 6 to 10 pens per treatment. Initiation of studies occurred directly after receiving or 2 to 3 months later following a period of grazing cornstalks. To determine initial and ending body weights, calves were limit-fed for 3 to 5 days to minimize the effects of rumen fill. Feeds and feed refusals were sampled weekly to determine DMI. Cattle were fed ad libitum in all studies. Actual body weights (BW) and average daily gain (ADG) were entered into the BCNRM (2016) model to determine predicted intake of the cattle during the study period. The predicted intake was then compared with the observed intake of the cattle to determine the accuracy of the prediction model of the data set. The difference between observed intake and predicted intake was determined as Observed DMI minus BCNRM Predicted DMI.

Of the 77 treatment means that were developed, 43 were utilized in this evaluation. Studies were grouped into 1 of 4 categories: Control (traditional forage-based diets with no distillers grains [DG]), Control DG (forage-based diets with DG), Corn Silage (corn silage-based diets), and Corn Silage DG (corn silage-based diets with DG). Due to a limited number of Corn Silage studies without DG, the Corn Silage and Corn Silage DG categories were combined.

Results

Observed and predicted intake were plotted across calculated TDN values to evaluate their relationship (Figure 1). As

Table 1. Observed versus predicted dry matter intake of different diet types[1]

	P-Value	R^2
Overall Means[2]	0.27	0.06
Control[3]	0.05	0.36
Control DG[4]	0.02	0.55
Corn Silage[5]	0.16	0.28

[1]Comparison of observed versus predicted dry matter intake using the BCNRM (2016) model

[2]All treatment means developed, n = 43

[3]Traditional forage-based diets with no distillers grains n = 16

[4]Traditional forage-based diets with distillers grains, n = 13

[5]Corn silage-based diets with and without distillers grains, n =14

Table 2. Observed versus predicted dry matter intake at different levels of TDN[1]

	P-Value	R^2
TDN < 64[2]	0.03	0.24
TDN > 64[3]	0.53	0.02

[1]Comparison of observed versus predicted dry matter intake using the BCNRM (2016) model

[2]Included all diets types with TDN < 64%, n = 19

[3]Included all diets types with TDN > 64%, n = 24

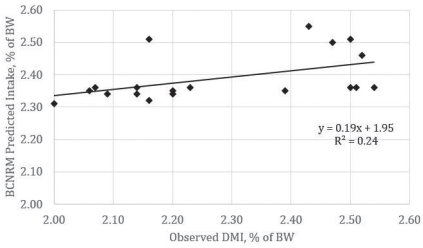

Figure 3. Observed versus Predicted DMI of Diets with TDN < 64. Plot of observed (43 treatments means) and BCNRM (2016) predicted dry matter intake of forage based diets (hay and corn silage based diets with and without distillers grains) with TDN values lower than 64%.

TDN increased, observed DMI increased linearly ($P < 0.01$) while predicted DMI had a quadratic response ($P < 0.01$), increasing up to 64% TDN and then decreasing with increasing TDN. The differences in DMI suggest the model may not correctly account for differences in diet type. Another possibility is the model inaccurately limits DMI of forage based diets when TDN gets above 64%. Because of the curvilinear response of the predicted DMI, the model may shift from a rumen fill limitation to an energetic fill around 64% TDN. However, the observed data would not agree with this intake pattern.

The difference between the observed DMI and the predicted DMI were plotted at differing levels of TDN (Figure 2). As TDN increased from 52.5 to 80.1% the difference between observed and predicted intake increased linearly ($P < 0.01$). At approximately 64% TDN, Observed DMI—Predicted DMI = 0; therefore, the model over predicted DMI for TDN < 64% and under predicted DMI in forage-based diets greater than 64% TDN.

Table 1 shows the strength of the model and the correlation between the predicted and actual intake of the overall treatment means and the different categories of diets. The model was not good at predicting intake of the overall means ($R^2 = 0.06$; $P = 0.27$). However, the model was more accurate within individual diet categories with the Control DG having the greatest correlation ($R^2 = 0.55$; $P = 0.02$). However, the model had relatively low R^2 values for all categories, suggesting it was not very accurate in predicting DMI of growing calves on any forage-based diets.

The lack of accuracy could be due to a lack of data points using high forage, low energy-based diets. The majority of the data used to build the BCNRM (2016) model may have been based on energy-dense growing diets or finishing based diets. The mechanisms that control intake are greatly different between these two types of systems and could be part of the reason that there were differences between the observed and predicted DMI when using forage-based diets.

Table 2 reports the strength of the model and the correlation between observed and predicted DMI of forage-based diets at differing TDN levels. Interestingly, when diets were less than 64% TDN ($R^2 = 0.24$; $P = 0.03$), the model had a higher correlation between observed and predicted intake than when the TDN of the diet was greater than 64% ($R^2 = 0.02$; $P = 0.53$).

A plot of all diet types with TDN lower than 64% was evaluated to determine the accuracy of the BCNRM (2016) model for high-forage, low-energy diets. The slope of the line comparing observed and predicted DMI was 0.19 (Figure 3). If the model accurately predicted intake, the slope of the line would be close to 1.0. The low slope indicates there are flaws in the prediction equation being used for low TDN forage-based diets.

The model does not accurately predict DMI in forage-based growing calf diets. However, the reasons why are not clear. There could be a multitude of reasons for the differences between the observed and predicted DMI including a lack of data using forage-based diets, extrapolation from more energy dense diets, or alterations in fill mechanisms.

Conclusion

The current BCNRM (2016) model does not accurately predict DMI of growing calves consuming forage-based diets when compared with observed data from similar sources of cattle, utilizing similar experimental procedures. The lack of predicted accuracy creates challenges when formulating diets for growing cattle fed high-forage diets and should lead to further evaluation of the current modeling system.

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Mineral Concentrations of Forages for Livestock in Nebraska and South Dakota

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Summary and Implications

Forage samples from Nebraska and South Dakota submitted to Ward Laboratories, Inc. from 2012–2019 were analyzed for mineral concentrations. Samples were categorized by forage species, quality based on protein content, and mineral concentration based on requirements for lactating beef cows. The data indicate that copper and zinc are frequently deficient across all species and levels of forage quality, emphasizing the need for supplementation. Except for magnesium, macro-mineral deficiencies are less likely to occur when feeding high quality forages in Nebraska and South Dakota. Corn feedstuffs are particularly likely to result in mineral deficiencies if fed without mineral supplementation. High protein annual small grain forages are more likely to have high tetany ratios than other forages. Forage mineral analysis can assist in determining whether or not supplementation is required and at what level. Forage mineral analyses is one component of developing a livestock mineral management strategy, in conjunction with livestock health and performance records, and overall ranch goals.

Introduction

Proper mineral nutrition is essential for strong immune systems, reproductive performance, and calf weight gain in beef cattle. Forages are the major component of beef cow diets in Nebraska and South Dakota. Moreover, mineral concentration in forages is highly variable due to differences in soil type, environmental conditions, species, and maturity. Laboratory analyses provide critical information that producers can use to compare mineral concentration in forages to beef cow requirements and develop appropriate supplementation strategies.

Procedure

Forage samples (n = 4,986) were submitted to Ward Laboratories, Inc. for mineral analysis from 2012–2019 by customers in Nebraska and South Dakota. Samples were sorted into eight forage categories (alfalfa, alfalfa grass mix, annual small grain forages, corn silage, corn stalks, earlage, perennial grass, and warm season annual grass) and classified into quality groups based on protein content. Samples were also categorized as deficient, ideal, or greater than maximum tolerable level based on mineral content in relation to nutrient requirements of a lactating beef cow in accordance with Nutrient Requirements of Beef Cattle (2016). Tetany ratios (seen below) were calculated and potential copper antagonisms identified.

$$\frac{K\% \times 256}{(Ca\% \times 499) + (Mg\% \times 823)}$$

Results

Data in Table 1 shows the percentage of forage samples within each category that are below animal requirements, could contribute to copper deficiency due to high sulfur or molybdenum, and/or are potentially tetany prone.

In general, macro-minerals including calcium (Ca), phosphorous (P), magnesium (Mg), sulfur (S) and potassium (K) were positively correlated with protein content of the forage (Table 2). These results suggest that macro-mineral deficiencies are more likely to occur in poor quality forages with lower protein concentrations.

A high percentage (75%) of perennial grass samples with less than 12% protein were deficient in phosphorous and magnesium. A high percentage of all corn feedstuffs (earlage, stalks, and silage) contained low levels of magnesium. Additionally, 59% corn silage and 100% of earlage samples contained low levels of Ca. These are important minerals for lactating cows and supplementation should be considered when utilizing these feedstuffs. Annual small grain forages with protein concentrations greater than 19% in Table 1 had a high percentage of samples (81%) with high potassium concentrations, and 59% of samples that would be considered tetany prone. These results would suggest that supplementation of Ca and Mg would be advisable if these forages were to be fed to lactating cows.

Micro-minerals including manganese (Mn), zinc (Zn), copper (Cu) were not correlated with protein content in all forage types. However, for Zn and Cu there were fairly strong positive correlations with protein content in perennial grasses, annual small grain forages, and warm season annual grasses. Many forage samples, regardless of species or quality, did not meet zinc and copper requirements for cows. A large proportion of earlage and corn silage samples also had concentrations below the manganese requirement. Although required in smaller quantities, micro-mineral supplementation is critical to reproduction, immune function, and general health.

Table 3 highlights the range in mineral concentrations of forages with moderate protein concentrations and quality. In general, reported data shows variation of mineral concentrations both greater than and less than the required level, and highlights the need for laboratory analysis to determine if mineral requirements can be met by forages alone and if not met by forages alone, analysis will help to determine the supplementation level that is needed.

Table 1. Percent of forage samples within each category that would be considered to result a defeciency[1] if not supplemented

	Concentration of mineral below animal requirement								Potential influence on copper absorption				
	Calcium	Phosphorous	Magnesium	Sulfur	Iron	Manganese	Zinc	Copper	Sulfur	Molybdenum	Iron	Potassium	Tetany Ratio
Type (Range % CP)	< 0.3 %	< 0.2 %	< 0.2 %	< 0.15 %	< 50 ppm	< 40 ppm	< 30 ppm	< 10 ppm	0.3–0.5%	2 -5 ppm	250–1000 ppm	>3.0%	> 2.2
Alfalfa													
Utility (< 16%)	0	29	38	22	3	53	75	81	5	18	28	9	2
Fair (16 to 17.9%)	0	16	17	2	0	57	84	80	9	17	27	18	0
Good (18 to 19.9%)	0	8	8	0	0	32	86	66	8	34	60	18	0
Premium (20 to 21.9%)	0	4	4	1	0	34	90	68	23	17	47	32	0
Supreme (≥ 22%)	0	0	2	1	0	24	64	62	21	30	57	63	0
Alfalfa grass mix	1	50	39	29	0	35	84	84	7	54	37	65	1
Perennial grass													
Low (< 5%)	12	100	94	86	0	36	100	100	0	50	45	0	0
Fair (5 to 8.9%)	5	86	80	57	0	17	90	98	1	32	26	1	1
Good (9 to 12.9%)	4	62	75	15	0	16	74	86	6	40	37	4	4
Premium (≥ 13%)	0	13	23	0	0	22	80	80	29	9	38	33	1
Annual small grains													
Fair (< 9%)	55	48	94	87	0	49	83	95		10	37	3	44
Good (9 to 12.9%)	30	13	83	19	0	11	62	97	3	11	50	19	32
Premium (13 to 18.9%)	11	2	44	0	0	8	25	92	8	17	33	28	15
Supreme (≥ 19%)	7	2	39	0	0	0	15	70	27	22	45	81	59
Annual warm season grass													
Low (< 5%)	7	57	74	90	0	67	78	89	0	0	33	3	3
Fair (5 to 8.9%)	7	59	5	94	0	32	80	94	0	5	42	6	3
Good (9 to 12.9%)	13	31	5	40	0	17	32	93	6	24	43	10	2
Premium (≥ 13%)	2	17	0	5	0	22	39	94	11	29	56	42	17
Corn feedstuffs													
Earlage	100	3	100	100	8	100	100	100	0	0	0	0	0
Corn stalks	21	84	78	10	0	28	75	94	0	0	66	3	7
Corn silage	59	16	79	87	0	69	84	96	0	1	15	2	4

[1]Assumes requirement for a lactating cow, which has greater Ca, P, and Mg requirements than a gestating cow, but micro mineral requirements would be similar. Categorization does not take into account bioavailability of the mineral in the forage.

Dark gray shading greater than 75% of samples may have resulted in a deficiency. Light gray shading between 50 and 75% of samples may have resulted in a deficiency

Table 2. Correlation of forage crude protein with mineral concentration

	Pearson correlation Coefficient							
	Ca	P	Mg	S	K	Mn	Zn	Cu
Alfalfa	**0.28**	**0.18**	**0.25**	**0.63**	0.10	**0.18**	**0.21**	**0.24**
Alfalfa grass mix	**0.69**	**0.62**	**0.55**	**0.80**	**0.69**	-0.14	0.13	0.18
Perennial grass	**0.55**	**0.71**	**0.50**	**0.67**	**0.74**	-0.06	**0.30**	**0.50**
Annual small grains	**0.38**	**0.62**	**0.55**	**0.82**	**0.62**	**0.37**	**0.54**	**0.60**
Annual warm season	**0.18**	**0.49**	**0.59**	**0.80**	**0.37**	0.15	**0.40**	**0.28**
Earlage	0.10	**0.44**	**0.32**	**0.70**	0.10	0.33	0.39	-0.29
Corn Stalks	0.08	**0.78**	**0.48**	**0.86**	**0.44**	0.38	0.23	0.40
Corn Silage	**0.54**	**0.39**	**0.52**	**0.72**	**0.50**	**0.32**	**0.40**	**0.14**
	P-value							
Alfalfa	**<0.01**	**<0.01**	**<0.01**	**<0.01**	0.09	**<0.01**	**<0.01**	**<0.01**
Alfalfa grass mix	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	0.39	0.43	0.26
Perennial grass	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	0.25	**<0.01**	**<0.01**
Annual small grains	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Annual warm season	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	0.07	**<0.01**	**<0.01**
Earlage	0.22	**<0.01**	**0.04**	**<0.01**	0.56	0.29	0.2	0.35
Corn Stalks	0.44	**<0.01**	**<0.01**	**<0.01**	**<0.01**	0.10	0.34	0.10
Corn Silage	<0.01	**<0.01**	**<0.01**	**<0.01**	**<0.01**	<0.01	<0.01	0.01

Table 3. Commonly observed[1] range of mineral concentrations[2]

	Calcium, %	Phosphorous, %	Magnesium, %	Sulfur, %	Manganese, ppm	Zinc, ppm	Copper, ppm
Lactating beef cow requirement	0.30	0.20	0.2	0.15	40	30	10
Good annual small grains (9 to 12.9% CP)	0.21–0.56	0.20–0.36	0.12–0.21	0.13–0.22	43–116	20–38	4–8
Good annual warm season grass (9 to 12.9% CP)	0.27–0.86	0.13–0.25	0.25–0.43	0.12–0.18	29–127	25–45	5–9
Good perennial grass (9 to 12.9% CP)	0.39–0.86	0.13–0.25	0.13–0.23	0.12–0.27	25–126	12–45	2–13
Good alfalfa (18 to 19.9% CP)	1.19–1.82	0.21–0.32	0.21–0.35	0.19–0.28	30–69	14–35	3–16
Fair alfalfa (16 to 17.9% CP)	1.10–1.76	0.19–0.32	0.20–0.32	0.16–0.28	24–55	17–30	5–11
Utility alfalfa (< 16% CP)	0.81–1.66	0.15–0.34	0.16–0.31	0.13–0.25	17–75	10–45	1.8[3]–19
Alfalfa Grass Mix	0.57–1.29	0.13–0.29	0.13–0.33	0.10–0.29	21–91	11–36	4–10

1 Average—or + one standard deviation

2 Bioavailability of minerals in forages is highly variable. Based on Nutrient Requirements of Beef Cattle by the National Research Council (2016) the following bioavailability can be assumed: 50% of calcium (Ca), 68% of phosphorus (P), 10–37% for magnesium (Mg) in hay and grass diets. Availability of manganese, zinc and copper are highly variable in forages. Availability of copper is decreased by the presence high amounts of antagonists, such molybdenum, iron, and sulfur, in the diet.

3 Minimum value, one standard deviation below average was negative

Conclusions

High protein forages, such as alfalfa and premium quality grass forages in this data set are less likely to be deficient in macrominerals. While some forages may provide adequate copper and zinc, these microminerals are likely to be deficient regardless of forage quality and species. Earlage and corn silage-based diets are specifically of concern for mineral deficiencies. High protein annual small grain forages are more likely than other forages to be tetany prone. Mineral analysis of forages is a tool that can be used when consulting with Extension professionals and other consultants to ensure beef cattle mineral requirements are being met to optimize production and performance.

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Training Improves the Reliability of Temperament Assessment in Cattle

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Summary with Implications

Accurate and precise measurement of docility in cattle is paramount when including temperament as a criterion for selection. The value of training individuals in assigning a docility score was evaluated by comparing the reliability of individual assessments of temperament in beef cattle before and after various instructional methods. Preceding training, participants' assessment of cattle behavior, videoed while each heifer was restrained in a chute, was not impacted by age, gender, or pre-existing cattle handling experience. Groups of participants that received additional training were more accurate and precise in evaluating temperament, regardless of training method, compared to those without. No matter an individual's prior beef cattle experience, they benefitted from the information provided in the training material. By completing a relatively short and targeted instructional program, producers can more reliably evaluate docility in their cattle, thereby enhancing their ability to incorporate temperament into their selection decisions within their herd.

Introduction

Strong behavioral responses of cattle towards humans or any other stressor have been associated with increased risk of handler injury. Additionally, such cattle have poorer weight gain and meat-eating quality, decreased tolerance to disease, and decreased reproductive performance, with increased production costs. Because of these effects, it is not uncommon for ranchers to make selection decisions based on an animal's behavior. Therefore, accurate and precise evaluation of docility in livestock is important for improvements in animal well-being, human safety, and profitability.

An animal's temperament is often subjectively evaluated as it is relatively straightforward to accomplish while working cattle. Research using such methods, however, report inconsistent classifications among evaluators, which affects the usefulness of subjective assessments. Consistency can be quantified by both the accuracy—the closeness of a measured value to a standard or known value—and precision—the closeness of two or more measurements to each other—of a set of measurements. Accuracy and precision are formally evaluated using inter- and intraobserver reliability, respectively.

Previous research has shown that chute scores are effective methods of measuring temperament and are consistently assessed by trained individuals (*2018 Nebraska Beef Cattle Report*, pp. 75–80). To assist the beef industry in benefitting from subjective evaluation of temperament, the objective of this study was to determine the impact of various training methods on improving reliability of behavior assessment in cattle restrained in a chute.

Table 1. Participant demographics by experience, age, and gender

		Group			
Category[1]	Level	C[4]	T1[5]	T2[6]	Total[7]
Experience[2]	Experienced	13	13	13	39
	Inexperienced	18	17	16	51
Age[3]	College	18	18	17	53
	Other	13	12	12	37
Gender	Male	16	17	16	49
	Female	15	13	13	41

[1] Categories determined using participants' responses to a questionnaire completed before the start of session 1.

[2] Experienced included "Expert (I work with cattle every day)" and "Competent (I work with cattle on a regular basis)" while Inexperienced included "Inexperienced (I work with cattle from time to time)" and "No experience".

[3] Age was grouped into "college" (19 to 22) and "other" (23 and up).

[4] Participants received no training and were not provided with a self-test.

[5] Participants viewed a training video prior to session 2.

[6] Participants viewed a training video and completed a self-test prior to session 2.

[7] Only participants who completed both sessions were included.

Procedure

Ninety individuals of varying age, gender, and cattle backgrounds were recruited to participate in the study, which was conducted on the East Campus of the University of Nebraska – Lincoln. Participants arrived to the first session (S1) and completed an animal experience questionnaire designed to collect information about previous animal handling experience and general demographics. Upon completion of the questionnaire, participants were shown 28 video clips (15 sec each) of cattle restrained in a chute and were asked to score each animal's temperament on a scale of 1 (docile) to 6 (aggressive). Unbeknownst to the participants, the video clips were a repetition of 14 videos shown twice. Data were collected using Qualtrics Survey Software.

The prerecorded video clips used were obtained from an earlier study of animal behavior conducted at the Virginia Tech Kentland farm, Virginia, U.S.A. As part of their assessment, heifers were previously given a subjective chute score by three trained individuals.

Participants were assigned in a balanced way to one of three treatments based on

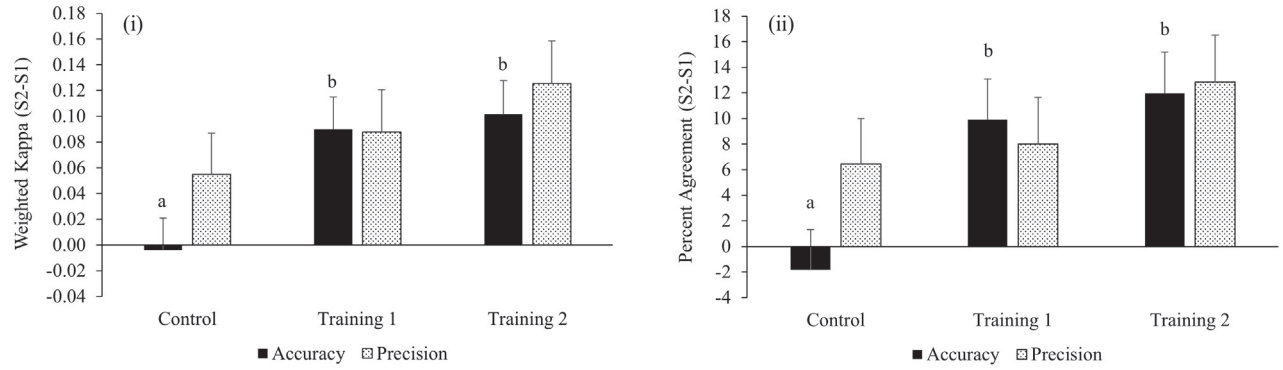

Figure 1. Comparison of accuracy (interobserver reliability) and precision (intraobserver reliability) from first (S1) to second (S2) session, shown as the difference in weighted Kappa coefficient (i) and the difference in percent agreement (ii) between sessions (S2 – S1). [a,b] Means with differing superscripts differ ($P < 0.05$).

their survey responses. They were asked to return one week later for a second session (S2) where they were shown another collection of video clips, as in S1. Assignment was based on cattle experience level (experienced, inexperienced), age (college, other), and gender (male, female). Final distribution of participants for each treatment is provided in Table 1.

The first group of participants served as the control (C, n = 31), receiving no training between sessions. Participants assigned to training program 1 (T1, n = 30) watched a 20-minute training video that discussed the scoring system in detail and included short video clips as illustrations. Participants assigned to training program 2 (T2, n = 29) watched the same training video as T1 but were then asked to complete a self-test consisting of 10 additional video clips. Participants assigned to T2 were then given the opportunity re-watch each clip and read an explanation regarding the scoring of each animal.

Statistical Analysis

Inter- and intraobserver reliabilities were calculated. Interobserver reliability measured accuracy by comparing an individual's score of a video clip to that of the trained experts collected the day the video was recorded. Intraobserver reliability measured precision by comparing a participant's scores when viewing the same video clip multiple times.

Using the statistical package R, reliabilities were evaluated by percent agreement (PA). The PA is the ratio of the number of times a participant's scores matched up—either the participant's score with the experts or the participant's score with themselves—with the total number of observations they provided. A PA of zero means no agreement while a PA of 100 means perfect agreement.

A further statistic, the weighted Cohen's Kappa (K) coefficient, was also obtained. The values of K vary from -1 to 1. Negative values indicate agreement is poorer than chance, a zero indicates agreement is entirely by chance, while positive values indicate agreement that is better than chance.

The effect of preexisting biases (experience level, age, and gender) on accuracy and precision during S1, and on the change in reliability between sessions, was also assessed. The SAS statistical package was used for these analyses. Least-squares means and their standard errors were obtained. The means were compared applying a Tukey's adjustment.

Results

Experience level, age, and gender had no effect on accuracy or precision when assigning chute score during S1. Individuals with prior cattle handling experience appeared to be no better or worse at assessing behavior than those without experience. Overall, accuracy (interobserver reliability) for S1 was 0.62 and 50.5% for K and PA, respectively. Precision (intraobserver reliability) for S1 was 0.66 and 56.1%, respectively.

To assess changes in accuracy and precision between sessions because of training, differences in the assigned chute scores between S1 and S2 were determined. There were still no effects of experience level, age, or gender on change between sessions ($P > 0.23$).

Training, however, improved the accuracy (interobserver reliability) of the assessments of temperament ($P < 0.01$). The values of K increased between sessions by 0.00 ± 0.02, 0.09 ± 0.03, and 0.10 ± 0.03 for C, T1, and T2, respectively. Although the two training methods improved accuracy compared to the control, the extent of that improvement did not differ between them (Figure 1). They did, however, result in final K values that were 0.68 ± 0.02 and 0.73 ± 0.02 for T1 and T2, respectively. The same outcome was observed for PA. Following the training, the PA improved to a similar extent for both training methods, with little change in the control (Figure 1). Clearly, the training video increased the accuracy of chute score assessment, regardless of treatment group. There was minimal additional benefit, however, in adding the self-test.

Conversely, precision (intraobserver reliability) increased between sessions not only for the two training methods but also for the control. That general improvement was to such an extent that size of the change did not differ among them ($P > 0.31$). The K values increased by 0.05 ± 0.03, 0.08 ± 0.03, and 0.13 ± 0.03 for C, T1, and T2, respectively. Increases in PA were also similar among the three groups (Figure 1). Arguably, since the increases in accuracy and precision were similar for T1 and T2, this lack of significance was due to the increase in precision within C.

Without training, the control group became more precise while, if anything, less accurate when assigning chute score; in other words, they became more consistently incorrect in their assessments of calf temperament. When chute scores are incorporated into a docility Expected Progeny Difference (EPD), less accurate evaluations of temperament are less a concern. Differences in mean scores across operations, which reflect accuracy, are accounted for in the genetic evaluation itself. In this case, increased precision is more beneficial than increased accuracy.

By viewing the training video, participants not only became more precise but also more accurate in assigning a chute score. In the commercial industry, where culling may be based on an animal's score during handling, misallocation may result in poorer decision-making. For instance, if a restless heifer (score 3) is deemed acceptable as a replacement cow but not a nervous one (score 4), those temperaments need to be accurately distinguished. Therefore, when selecting cattle based on their phenotype alone, or when comparing the temperaments of cattle across operations, scores need to be assigned both accurately and precisely.

Implications/Conclusions

Prior to training, individual assessments of temperament of beef cattle behavior while restrained in a chute were inexact. Such was the case regardless of prior cattle handling experience, age, or gender. Precise measurements are important for reliable genetic evaluations. When selecting, or culling, cattle based on their assigned chute score, accuracy also matters. Incorporation of a short training video significantly increased participants' ability to assess chute score. When producers make decisions within their operation to select for docile cattle, it is imperative that these decisions are as accurate and precise as possible. When they are, improvements in the overall temperament of a herd can be achieved more quickly. To assist those producers wishing to gain skills in assigning chute scores, the training video, as well as some additional materials, are available online at https://beef.unl.edu/learning-modules.

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Evaluating Finishing Performance of Cattle Fed High-Moisture Corn and Steam-Flaked Corn Blends with Modified Distillers Grains

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Summary with Implications

The objective of this study was to determine the impacts of feeding different inclusions of high-moisture corn or steam-flaked corn in diets with 20% modified distillers grains plus solubles. Additionally, this study was designed to quantify any associative effects when high-moisture and steam-flaked corn are blended together with modified distillers grains plus solubles. Cross-bred yearling steers (n=90; BW=777 ± 7.9 lb) were individually fed using a Calan Gate system for 168 days. Animals received one of five finishing diets containing 100% high-moisture corn, one of three blends of high-moisture:steam-flaked, or 100% steam-flaked corn to determine the optimum inclusion of the corn types with distillers grains. There was no difference in dry matter intake, but final body weight, average daily gain, and feed conversion all linearly increased as steam-flaked corn inclusion increased. In conclusion, no associative effects were observed and feeding steam-flaked corn with 20% modified distillers resulted in the greatest performance.

Introduction

Steam-flaked corn (SFC) has been widely used in feedlots in the southern United States to improve feed conversion (F:G) by increasing starch digestibility. Similarly, feedlots in the Midwest have commonly fed high moisture corn (HMC), both to ensure corn supply for the year and to improve F:G when fed with distillers grains. Popularity of SFC in the Midwest is increasing, but producers still realize the benefits of HMC based on price and supply. Additionally, while both SFC and HMC are rapidly fermented in the rumen, it is possible that rates of fermentation differ enough so that ruminal starch digestion is slowed and a positive associative effect may be observed when feeding HMC and SFC in combination. Distillers grains has also become a staple ingredient to provide protein and energy in finishing diets. Steam-flaked corn has an improved F:G compared to HMC when fed without distillers; however, when distillers is included up to 40% of the diet on a dry matter (DM) basis, HMC has an advantage over SFC (*2007 Nebraska Beef Cattle Report*, pp 33–35). Similarly, SFC has improved F:G compared to dry-rolled corn (DRC) when fed without byproducts, but when both corn types are fed with 35% WDGS, performance was similar (*2012 Nebraska Beef Cattle Report*, pp 70–72). Therefore, the objective was to determine the implications of feeding different inclusions of HMC or SFC when modified distillers grains plus solubles (MDGS) was included at 20% of the diet on a DM basis. Additionally, this study was designed to determine if positive associative effects are observed when HMC and SFC were fed together with MDGS.

Table 1. Composition of steam-flaked corn and high-moisture corn based finishing diets containing 20% modified distillers grains plus solubles

	Treatments				
HMC%	100	75	50	25	0
SFC%	0	25	50	75	100
Ingredient					
SFC[1]	0.00%	17.50%	35.00%	52.50%	70.00%
HMC[2]	70.00%	52.50%	35.00%	17.50%	0.00%
MDGS	20.00%	20.00%	20.00%	20.00%	20.00%
Grass Hay	6.00%	6.00%	6.00%	6.00%	6.00%
Supplement[3]	4.00%	4.00%	4.00%	4.00%	4.00%

[1]SFC- Steam-flaked corn average 29.9 lb/bu

[2]HMC- High moisture corn (70% DM rolled and stored in bunker)

[3]Supplement—Formulated to provide 1.37% fine ground corn, 1.64% limestone, 0.10% tallow, 0.50% urea, 0.30% salt, 0.05% beef trace mineral, 0.015% vitamin ADE, and provide 30 g/ton rumensin-90 and 8.8 g/ton tylan-40

Procedure

The relationship between HMC and SFC in diets with distillers was explored at the Eastern Nebraska Research and Extension Center (ENREC) to compare finishing cattle performance when fed HMC, SFC, or a blend with 20% MDGS. This study utilized 90 yearling steers (777 ± 7.9 lb) individually fed using the Calan gate system. Treatments included (Table 1): 100% HMC, 75% HMC blended with 25% SFC, a 50% blend of the grains, 25% HMC blended with 75% SFC, or 100% SFC (DM basis); as the grain included at 70% of the diet). Steam flaked corn averaged 29.9 lb/bu and was delivered three times per week from a local commercial feedlot near Memphis, Nebraska (Raikes Feedyard). High moisture corn was harvested, rolled in a roller mill, and stored in bunkers prior to initiation of this trial. Corn was fed at 70% DM in this study. Modified distillers grains plus solubles was fed at 20% of the diet (DM basis), which reflects current industry inclusions. Additionally, all diets contained 6% grass hay and a 4% supplement, which was formulated with 0.5% urea, 30 g/ton rumensin (Elanco Animal Health), and 8.8 g/ton of tylan (Elanco Animal Health). Animals were implanted on day 1 with a Revalor IS (Merck Animal

Table 2. Effect of steam-flaked corn and high-moisture corn inclusion in finishing diets fed with 20% MDGS on performance characteristics

	Treatment					P-value		
HMC%[1]	100	75	50	25	0			
SFC%[2]	0	25	50	75	100	SEM	Linear	Quad
Initial BW, lb	774	775	782	778	776	12.87	0.84	0.75
Car. Adj. FBW[3], lb	1365	1366	1410	1408	1429	20.41	0.009	0.94
DMI, lb	22.3	22.4	22.6	22.1	23.0	0.46	0.50	0.66
ADG, lb	3.53	3.52	3.74	3.75	3.89	0.09	< 0.01	0.80
F:G[4]	6.35	6.41	6.07	5.92	5.91	0.123	< 0.01	0.91
HCW[5], lb	860	861	889	887	900	12.85	< 0.01	0.94
LM Area, in^2	13.9	14.1	14.1	14.6	14.4	0.337	0.12	0.75
Fat, in	0.54	0.56	0.65	0.62	0.65	0.04	0.01	0.52
Marbling[6]	522	524	520	502	549	22.36	0.65	0.33
Dressing, %	62.4%	62.9%	62.7%	62.9%	63.5%	0.004	0.09	0.70

[1]HMC%—percent of total corn that is fed as high-moisture corn

[2]SFC%—percent of total corn that is fed as steam-flaked corn

[3]Car Adj. FBW—calculated based on HCW/common 63% dress

[4]F:G—analyzed statistically as G:F

[5]HCW—hot carcass weight

[6]400 = Small 00, 500 = Modest 00, 600 = Moderate 00

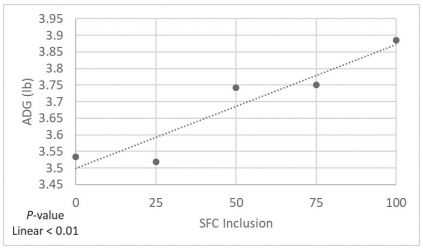

Figure 1. Average daily gain (ADG) of finishing steers fed high moisture corn (HMC), steam-flaked corn (SFC), or a blend of the two grains with 20% modified distillers grains plus solubles.

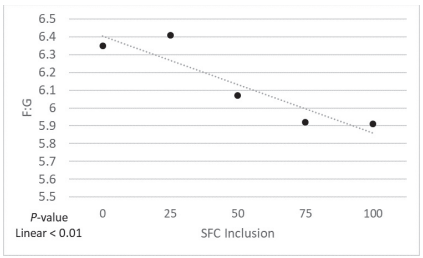

Figure 2. Feed conversion of finishing steers fed high moisture corn (HMC), steam-flaked corn (SFC), or a blend of the two grains with 20% modified distillers grains plus solubles.

Health) and then reimplanted on day 57 with a Revalor 200 (Merck Animal Health). Cattle were on feed 168 days. Initial BW was determined based on an average of 3 day BW following 5 days of limit feeding to equalize gut fill. Before slaughter, a 1 day live final BW was collected and animals were slaughtered at a commercial abattoir. During harvest, hot carcass weight (HCW) was recorded and carcass adjusted final BW was calculated based on a common 63% dressing percentage. Carcass characteristics included marbling, 12th rib fat thickness, and *Longissimus* muscle (LM) area were collected following a 48-hour chill.

Data were analyzed using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, N.C.) as a completely randomized design with cattle stratified by initial body weight (BW) and animal as the experimental unit. This resulted in 18 replications per treatment. The model included the proportion of SFC and HMC. Linear and quadratic contrasts were developed to quantify if a positive or negative associative effect occurred between SFC and HMC when fed with 20% MDGS.

Results

Results showed no differences in initial BW, dry matter intake, longissimus muscle area, or marbling score between treatments ($P > 0.12$; Table 2). Ending BW, HCW, ADG (Figure 1), and F:G all linearly improved with increasing inclusion of SFC in the diet ($P < 0.05$). Carcass adjusted F:G improved linearly ($P < 0.01$; Figure 2) from 6.35 to 5.91 for 100% HMC compared to 100% SFC diets, respectively. This improvement in F:G was a result of an increase in ADG from 3.53 to 3.89 lbs/d in favor of the 100% SFC diet. Dry matter intake was similar across all treatments at 22.5 lbs. No quadratic response was detected for any measure collected in this trial. These performance data suggest that feeding blends of SFC and HMC did not result in an associative effect and replacing HMC with SFC resulted in a linear improvement in ADG and F:G. The results of this study differ from previous work, but deoiled MDGS was used in this study compared to full fat wet distillers grains plus solubles in previous work.

Conclusion

In conclusion, feeding steam-flaked corn in finishing diets resulted in improved performance compared to high-moisture corn in diets containing 20% modified distillers grains plus solubles. The increasing popularity of feeding steam-flaked corn in the Midwest with modified distillers grains plus solubles included in the diet is a viable option and may improve feed efficiency when compared to traditional high-moisture corn based diets. However, increased processing costs associated with the steam flaking process must be analyzed to determine profitability in this system.

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Evaluation of Processing Technique for High-Moisture and Dry Corn Fed to Finishing Cattle

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Summary with Implications

A 134-day finishing trial was conducted to evaluate the effect of milling method and corn type on finishing cattle performance and carcass characteristics. Treatments were applied in a 2 × 3 factorial arrangement, with the first factor as milling method (Automatic Ag roller mill or hammer mill) and the second factor as corn type, either 100% dry corn, 50:50 blend of dry and high moisture corn, or 100% high moisture corn. There was no interaction between milling method and corn type for carcass-adjusted final body weight, average daily gain, or dry matter intake but there was an interaction between milling method and corn type for feed conversion. Cattle fed the diet containing 100% high moisture corn processed with the Automatic Ag roller mill were 4.7% more efficient than cattle fed a 100% high moisture corn-based diet processed with a hammer mill. There was no effect on carcass characteristics based on milling method or corn type. Processing high-moisture corn using Automatic Ag's roller mill improved feed conversion compared to processing with a hammer mill, but processing method had little effect on dry corn or blended diets.

Introduction

Corn is processed in feedlot finishing diets to increase starch digestion and improve feed conversion. While the effect of corn processing method has been extensively studied, prior research was conducted before the widespread use of distillers grains plus solubles in finishing diets. Therefore, the objective of this experiment was to evaluate the effect of using Automatic Ag roller mill or a hammer mill to process dry corn or high-moisture corn in diets containing 20% wet distillers grains plus solubles (WDGS).

Table 1. Composition (DM basis) of diets fed to steers to evaluate the effect of processing technique and corn type on animal performance and carcass characteristics.

	Auto Ag Roller Mill			Hammer Mill		
	DC	DC:HMC	HMC	DC	DC:HMC	HMC
Dry corn	70	35	-	70	35	-
High-moisture corn	-	35	70	-	35	70
Wet Distillers + Solubles	20	20	20	20	20	20
Corn Stalks, ground	5	5	5	5	5	5
Supplement [1]	5	5	5	5	5	5

[1] Supplement formulated to provide 390 mg/steer daily of monesin, 90 mg/steer daily of tylosin, and a vitamin + trace mineral package

Table 2. Particle size distribution by percentage for dry corn (DC) and high moisture corn processed by Automatic Ag (AA) roller mill or hammer mill

	AA Roller Mill		Hammer Mill	
Screen Size, µm	DC	HMC	DC	HMC
6300	1.7	9.7	10.9	30.1
4750	29.5	34.5	8.3	18.7
3350	39.8	26.1	15.8	22.2
1700	23.8	17.3	29.0	20.9
1410	1.3	2.1	11.6	2.1
850	1.7	3.8	8.5	2.9
600	0.5	2.0	5.3	1.1
<600	1.7	4.5	10.7	1.7
Geometric mean diameter, µm	3514	2867	1808	2248
Geometric standard deviation, µm	1160	1335	924	501

Materials and Methods

A feedlot study was conducted at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE. Crossbred steers (n=600; initial BW = 885 lb; SD = 37 lb) were used in an experiment with a 2 × 3 factorial design. Factors consisted of two milling methods (roller mill or hammer mill) and corn fed one of three ways [100% dry corn, 50:50 blend, or 100% high-moisture corn (HMC)] for a total of 60 pens with 10 replications per treatment and 10 steers/pen. The roller mill (Automatic Ag, Pender, NE) was used for both dry and high-moisture corn and two hammer mills were used: Haybuster (Jamestown, ND) for high-moisture corn and Might Giant Tub Grinder (Jones Manufacturing, Beemer,

Table 3. Simple effects of milling method and corn type on performance and carcass characteristics of finishing steers

	Auto Ag Roller Mill			Hammer Mill							
	DC	DC:HMC	HMC	DC	DC:HMC	HMC	SEM	Corn Type P-Value	Mill Type P-Value	Corn x Mill Type	Roller vs Hammer HMC
Initial BW, lb	884	884	884	886	884	887	1.0	0.35	0.03	0.54	0.08
Carcass-Adj. Performance											
Final BW, lb[1]	1483	1478	1483	1486	1479	1464	9.0	0.44	0.44	0.35	0.10
DMI, lb/d	28.6	27.9	26.4	28.8	27.9	26.7	0.28	<0.01	0.46	0.86	0.46
ADG, lb	4.49	4.46	4.49	4.49	4.46	4.32	0.07	0.42	0.32	0.32	0.07
F:G	6.37^{bc}	6.25^{bc}	5.88^{a}	6.41^{c}	6.25^{bc}	6.17^{b}	-	<0.01	0.07	0.09	<0.01
NEm, mcal/lb[2]	0.84	0.86	0.90	0.84	0.86	0.87	0.008	<0.01	0.07	0.10	<0.01
NEg, mcal/lb	0.55	0.57	0.61	0.55	0.57	0.58	0.007	<0.01	0.04	0.16	<0.01
ME, mcal/lb	1.27	1.28	1.34	1.27	1.28	1.30	0.010	<0.01	0.06	0.10	<0.01
Carcass Characteristics											
HCW, lb	934	932	935	936	932	922	5.7	0.45	0.43	0.34	0.10
Dressing Percent	61.8	62.4	62.4	62.0	62.3	61.8	0.24	0.18	0.40	0.25	0.08
LM area, in sq.	14.3	14.6	14.7	14.6	14.7	14.6	0.17	0.29	0.46	0.31	0.52
Marbling score[3]	484	515	475	488	477	474	10.7	0.12	0.18	0.09	0.99
12th rib fat thickness, in.	0.53	0.52	0.51	0.50	0.51	0.50	0.02	0.93	0.14	0.66	0.64
Calculated YG [4]	3.29	3.10	3.09	3.20	3.15	3.10	0.06	0.05	0.50	0.52	0.86
Liver Abscess, %	28	27	38	24	29	27	5.8	0.19	0.43	0.37	0.13

[a, b, c] Means within a row and without common superscripts differ ($P \leq 0.05$)

[1] Final BW adjusted to a common dressing percent of 63%

[2] Values calculated using equations from Galyean et al. and are based on intake and performance of cattle

[3] 400 = small, 500 = modest, 600=moderate

[4] Yield grade = 2.5 + (2.5 * BF, in)—(0.32 * LM area, in^2) + (0.2 * 2.5, KPH %) + (0.0038 * HCW, lb) where KPH is assumed to be 2.5%.

NE) for dry corn. Both HMC and dry corn were processed using a 5/8" screen in the hammer mill, and the roller mill was adjusted as needed to ensure all kernels were broken. High moisture corn was harvested and processed in September 2018 and kept in a bunker until trial initiation in May of 2019. Dry corn was processed as needed throughout the feeding period. Before trial initiation, cattle were limit-fed a common diet consisting of 50% Sweet Bran (Cargill, Blair, NE) and 50% alfalfa hay for 5 consecutive days to minimize BW variation due to gut fill. Cattle were weighed on two consecutive days and averaged to establish initial BW. Blocking criteria were related to start time and BW. Two BW blocks were used in the first start block (4 reps in light block and 1 rep in heavy block) and 1 BW block in the second start block, resulting in three total blocks. Cattle were fed ad libitum once daily at approximately 0800. Cattle were adapted to finishing rations over 23 days with corn replacing alfalfa hay [32.5% corn and 37.5% alfalfa hay (DM-basis), initially, with corn replacing alfalfa in 10% (DM-basis) increments]. All finishing diets included (DM-basis; Table 1): 70% corn (DC, 50:50 blend, or HMC), 20% wet distillers grains plus solubles, 5% ground corn stalks and 5% supplement. The supplement was formulated to provide 90 mg/steer tylosin, 390 mg/ steer monensin daily (30 g/ton of DM concentration), and 0.5% urea in the diet as well as a calcium, salt, vitamin and trace minerals to meet or exceed requirements.

Cattle were implanted with Revalor-IS (80 mg trenbolone acetate + 16 mg estradiol; Merck Animal Health) on d 1 and reimplanted with Revalor-200 (200 mg trenbolone acetate + 20 mg estradiol; Merck Animal Health) on d 50. Steers were fed for 134 days and harvested at a commercial abattoir (Greater Omaha Packing, Omaha, NE). Hot carcass weight and liver score were recorded on harvest date, and LM area, USDA marbling score, and fat depth were collected following a 48-hour chill using camera data. Final live BW was calculated using the pen average final live BW pencil shrunk 4% to adjust for fill. Carcass-adjusted performance was calculated by dividing hot carcass weight by a common dressing percentage of 63%.

Samples of dry corn and HMC were taken at trial initiation and reimplant time and used for particle size determination. Samples were used to determine corn particle size distribution, geometric mean diameter, and geometric standard deviation for each processing method.

Data were analyzed as a 2 × 3 factorial design with the main effects of mill type and corn type and the appropriate interaction. The MIXED procedure of SAS was

Table 4. Main effect of corn type on steer performance and carcass characteristics

	DC	DC:HMC	HMC	SEM	Corn Type P-Value
Initial BW, lb	885	884	885	0.8	0.35
Carcass-Adj. Performance					
Final BW, lb [1]	1484	1479	1473	6.7	0.44
DMI, lb/d	28.7[a]	27.9[b]	26.5[c]	0.21	<0.01
ADG, lb	4.49	4.46	4.41	0.05	0.42
Live Performance					
Final BW, lb	1510[a]	1497[ab]	1495[b]	5.6	0.07
Dressing percent	61.9	62.2	62.1	1.9	0.18
NEm, mcal/lb[2]	0.84[b]	0.86[b]	0.89[a]	0.005	<0.01
NEg, mcal/lb	0.55[c]	0.57[b]	0.59[a]	0.005	<0.01
ME, mcal/lb	1.27[b]	1.28[b]	1.32[a]	0.007	<0.01
Carcass Characteristics					
HCW, lb	935	932	928	4.2	0.45
LM area, in sq.	14.4	14.7	14.6	0.12	0.29
Marbling score [3]	486	496	474	7.9	0.12
12th rib fat thickness, in.	0.51	0.51	0.51	0.011	0.93
Calculated YG [4]	3.24[b]	3.12[ab]	3.09[a]	0.048	0.05
Liver Abscess, %	26	28	33	4.0	0.19

[a, b, c] Means within a row and without common superscripts differ (P ≤ 0.05)

[1] Final BW adjusted to a common dressing percent of 63%

[2]Values calculated using equations from Galyean et al. derived from the NRC (1996) and are based on intake and performance of cattle

[3] 400 = small, 500 = modest, 600=moderate

[4] Yield grade = 2.5 + (2.5 * BF, in.)—(0.32 * LM area, in^2) + (0.2 * 2.5, KPH %) + (0.0038 * HCW, lb.) where KPH is assumed to be 2.5%.

used for performance and carcass characteristics with start block and treatment as fixed effects. Liver data were analyzed using GLIMMIX as a binomial distribution. Alpha values of ≤ 0.05 were considered significant and 0.05 ≤ α ≤ 0.10 was considered a tendency.

Results

As expected, the Automatic Ag roller mill had a numerically greater geometric mean diameter and a greater percentage of particles retained on sieves greater than 1700 µm, but less than 6300 µm (whole kernel) compared to the hammer mill (Table 2). The average weekly DM of the roller HMC and DC were 68.2% and 90.0%, respectively, and the average DM of the hammer mill HMC and DC were 65.4% and 89.6% for the duration of the feeding period. Weekly ingredient DM were adjusted weekly to correct % of diets on an as-fed basis when loaded to ensure accuracy for DM inclusions.

There were no interactions between corn type × milling method (Table 3) for carcass-adjusted final weight, DMI, or ADG ($P \geq 0.32$), but there was a tendency for an interaction between corn type and milling method for feed conversion ($P = 0.09$). Steers fed the HMC diet processed with the roller mill had an improvement of feed efficiency of 4.7% ($P < 0.01$) over HMC processed with the hammer mill. The DC:HMC blended diets processed with either mill type and DC diets processed with the roller mill were intermediate, but not different than DC processed with the hammer mill. This F:G response is further explained by a tendency between corn type and milling method for NEm and metabolizable energy ($P = 0.10$; Table 3). There were no interactions between corn type × milling method for HCW, dressing percent, LM area, 12th rib fat thickness, calculated yield grade, or liver abscess percent ($P \geq 0.25$), but there was a tendency for an interaction between corn type and milling method for USDA marbling score ($P = 0.09$). It is important to note that there was a high incidence of liver abscesses in this trial suggesting that cattle were challenged from an acidosis perspective as anticipated with a high concentrate ration. The lack of significant differences across treatments suggests acidosis is not influencing treatments outcomes. Due to the lack of an interaction for many variables, main effects of corn type and milling method are presented except for feed conversion.

There were no significant differences in final BW or ADG ($P \geq 0.42$) when evaluated on a carcass basis (corrected to common dressing percent of 63%) based on corn type (Table 4). Cattle fed the DC based diet had the greatest DMI ($P < 0.01$), the DC:HMC blended diet was intermediate and the HMC cattle had the lowest DMI. The differences in DMI are likely due to energy content (HMC being greater than dry corn) and greater acidosis potential of the HMC. Evaluating performance on a carcass-adjusted basis is more repeatable and estimating final weight from carcass weight is a better method for comparison of treatments. It appears gut fill lead to an increase in final live BW for cattle fed dry corn which was not translated to better carcass weight, thus lower dressing percent. High-moisture corn diets provided significantly more dietary energy in the diets ($P \leq 0.01$) compared to DC:HMC or DC alone (Table 4). There were no differences due to corn type for HCW, dressing percent, LM area, USDA marbling score, 12th rib fat thickness, or liver abscess percent ($P \geq 0.12$); however, steers fed HMC diets had a lower ($P = 0.05$) calculated YG compared to DC, but neither treatment differed from DC:HMC.

There was no effect on carcass-adjusted final BW, ADG, or DMI based on mill type ($P \geq 0.15$; Table 5). Diets processed with the roller mill had greater NEg ($P = 0.04$), and there was a tendency for the roller mill diets to have greater NEm and ME ($P \leq 0.07$) compared to processing with the

Table 5. Main effect of milling method on steer performance and carcass characteristics

	Auto Ag Roller Mill	Hammer Mill	SEM	Mill Type P-Value
Initial BW, lb	884	885	0.65	0.03
Carcass-Adj. Performance				
Final BW, lb [1]	1482	1476	5.7	0.44
DMI, lb/d	27.6	27.8	0.17	0.46
ADG, lb	4.48	4.42	0.042	0.32
Live Performance				
Final BW, lb	1502	1499	4.7	0.65
Dressing percent	62.2	62.0	1.6	0.40
NEm, mcal/lb[2]	0.87	0.86	0.005	0.07
NEg, mcal/lb	0.58	0.57	0.005	0.04
ME, mcal/lb	1.30	1.28	0.005	0.06
Carcass Characteristics				
HCW, lb	933	930	3.6	0.43
LM area, in sq.	14.5	14.6	0.10	0.46
Marbling score [3]	491	480	6.8	0.18
12th rib fat thickness, in.	0.52	0.50	0.010	0.14
Calculated YG [4]	3.16	3.15	0.041	0.50
Liver Abscess, %	31	27	4.0	0.43

[a, b, c] Means without common superscripts differ

[1] Final BW adjusted to a common dressing percent of 63%

[2] Values calculated using equations from Galyean et al. derived from the NRC (1996) and are based on intake and performance of cattle

[3] 400 = small, 500 = modest, 600=moderate

[4] Yield grade = 2.5 + (2.5 * BF, in.)—(0.32 * LM area, in^2) + (0.2 * 2.5, KPH %) + (0.0038 * HCW, lb.) where KPH is assumed to be 2.5%.

hammer mill (Table 5). There was no effect of milling method on carcass characteristics ($P \geq 0.14$).

Conclusion

Overall, high-moisture corn processed with the roller mill improved feed conversion in finishing cattle by approximately 5% compared to hammer milling. Milling method also impacted particle size with less whole kernels in high-moisture corn processed with the roller mill and less small particles in dry corn processed with the Automatic Ag Roller Mill compared to hammer milling. Feeding high-moisture corn resulted in lower intake and similar gain, which improved feed conversion compared to dry corn, with DC:HMC being intermediate. Aside from the improved feed conversion by processing corn with the roller mill, there were no other impacts of milling method on cattle performance or carcass characteristics. Overall, these data suggest that processing high-moisture corn with the Automatic Ag roller mill improved conversion by approximately 5%.

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Impact of Feeding *Aspergillus* Subspecies Blend and Different Corn Processing Methods on Finishing Beef Cattle Performance and Carcass Characteristics

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Summary with Implications

A feedlot study utilizing 320 crossbred calf-fed steers (initial body weight 588 lb) compared the effect of feeding an Aspergillus additive in either dry-rolled corn or high-moisture corn finishing diets on cattle performance and carcass characteristics. Steers were fed 0 g/steer daily or 10 g/steer daily Aspergillus for both corn processing methods. There were no significant interactions between corn processing method and Aspergillus. Feeding finishing cattle Aspergillus did not impact performance compared to feeding none. Cattle fed dry-rolled corn had greater final body weight, dry matter intake, and gain compared to high-moisture corn diets. But cattle fed high-moisture corn had a 6.25% decrease in feed-to-gain compared to dry-rolled corn. These data suggest that feeding Aspergillus does not affect performance. The lower dry matter intake and average daily gain observed would suggest a potential acidosis problem for high-moisture corn compared to dry-rolled corn-based finishing diets.

Introduction

Aspergillus ssp. blend (Dried aspergillus ssp. fermentation product [SSF – Starch]; Provita Supplements) is a feed supplement that contains dry powdered *Aspergillus oryzae* and fermentation product to significantly increase the presence of alpha-amylase enzyme in cattle rumen. This increased enzyme activity and fungal/bacterial growth could increase starch digestion potentially leading to an improvement in animal performance. In addition, *Aspergillus oryzae* increases the growth rate of *Megasphaera elsdenii*, thereby increasing lactate utilization in the rumen. The increase in lactate utilization could slow the decline of ruminal pH post-feeding, preventing ruminal acidosis. Previous research has observed an increase in dry matter intake (DMI) and average daily gain (ADG) in the initial 28-d on feed for dry cracked and high-moisture corn diets. A 7.2% decrease in feed to gain ratio (F:G) was observed when *Aspergillus* was added to a dry whole-shelled corn diet fed to finishing steers. However, no decrease in F:G was observed when finishing steers were fed high-moisture corn with *Aspergillus*. The response of *Aspergillus* has been variable over studies, dependent on grain processing method and researched without the utilization of distillers grains.

Therefore, the objective of this study was to evaluate the effect of feeding *Aspergillus* in dry-rolled corn (DRC) and high-moisture corn (HMC) based finishing diets on performance and carcass characteristics of beef cattle in diets with 25% modified distillers grains plus solubles (MDGS).

Procedure

Crossbred calf-fed steers (n = 320; 588 lb. ± 20 lb.) were limit-fed a diet consisting of 50% alfalfa hay and 50% Sweet Bran (Cargill Wet Milling; Blair, NE) at 2% BW for five consecutive days to equalize gut fill. Steers were weighed across two consecutive days (d0 and d1) to establish the initial weight (588 lb. ± 20). Cattle were assigned to pens following the first day weight and stratified based on that weight to ensure equal, yet random allotment to pens. Pens were assigned randomly to treatment. Cattle were started on treatments following the 2-day limit fed weighing. A 21-d adaptation period was utilized with alfalfa hay decreasing and corn increasing, while MDGS and supplement amounts remained unchanged.

Four treatments were evaluated as a 2 × 2 factorial design. One factor included two corn processing methods in the diets as either DRC or HMC. The second factor included feeding 0 or 10 g/steer daily of Aspergillus ssp. blend (aspergillus ssp. fermentation product [SSF – Starch]; Provita Supplements). Treatment diets are provided in Table 1. The trial evaluated four treatments, with 80 steers and 8 pens per treatment. The study consisted of three weight blocks and eight replications within each treatment for a total of thirty-two pens on trial with 10 steers/pen.

Steers were poured with Permectrin CD (Boehringer Ingelheim Vetmedica, Inc.) and weighed individually on d52 and d92. Steers were implanted with Revalor IS (Merck Animal Health) on d1 and re-implanted with Revalor-200 (Merck Animal Health) on d92. On d96 a lower inclusion of *Aspergillus* ssp. blend (12.2 g/steer daily to 10 g/steer daily) was utilized as dry matter intakes were at the targeted 22 lb/d. On d164 Optaflexx (Elanco Animal Health) was included in the diet at 300 mg/steer daily until d196.

After 197 days, cattle were pen weighed, and loaded in the afternoon after feeding 50% of the previous day's intake. Ending live weight was based on live body weight collected on the afternoon prior to slaughter. On the day of harvest, kill order, liver abscess scores and HCW were recorded and carcass-adjusted final BW was calculated from a common 63% dressing percentage. Carcass-adjusted final BW was used to determine ADG and F:G. Carcass characteristics included marbling score, longissimus muscle area and yield grade; which were recorded after a 48-hr chill.

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.) as a generalized randomized block design, with pen as the experimental unit and block as a fixed effect. Data were analyzed as a 2 × 2 factorial, evaluating an interaction between grain processing and feeding Aspergillus ssp. blend. If no interaction was detected, then main effects of corn processing and inclusion of Aspergillus ssp. blend were evaluated.

Table 1. Dietary treatment composition (DM basis) for finishing steers fed dry-rolled corn or high-moisture corn with or without *Aspergillus*

	Treatments			
Corn Processsing:	DRC	DRC	HMC	HMC
Aspergillus:	0 g/d	10 g/d	0 g/d	10 g/d
Dry-rolled corn (DRC)	64	64	-	-
High-moisture corn (HMC)	-	-	64	64
Grass Hay	6	6	6	6
Modified distillers grains (MDGS)	25	25	25	25
Supplement	5	5	5	5
Fine Ground Corn	2.62	2.52	2.62	2.52
Limestone	1.5	1.5	1.5	1.5
Aspergillus	--	0.122 or 0.10	--	0.122 or 0.10
Commercial Grade Dye	+	-	+	-
Urea	0.5	0.5	0.5	0.5
Salt	0.3	0.3	0.3	0.3
Trace Mineral	0.05	0.05	0.05	0.05
Vitamin ADE	0.015	0.015	0.015	0.015
Rumensin-90[1]	0.0165	0.0165	0.0165	0.0165
Tylan-40[2]	0.009	0.009	0.009	0.009

[1] Supplement formulated to provide 30 g/ton Rumensin® (Elanco Animal Health, DM basis)

[2] Supplement formulated to provide 8.8 g/ton Tylan® (Elanco Animal Health, DM basis)

Table 2. Main effect of feeding *Aspergillus* at either 0 or 10 g/d on cattle performance and carcass characteristics

	Treatment			
	0 g/d	10 g/d	SEM	P-Value
Pens, *n*	8	8	--	--
Initial BW, lb	588	588	0.5	0.81
Carcass-Adjusted Performance				
Final BW, lb[1]	1289	1275	8.1	0.24
DMI, lb/d	21.6	21.2	0.16	0.14
ADG, lb[1]	3.56	3.49	0.042	0.25
F:G[1]	6.06	6.06	--	0.78
Carcass Characteristics				
HCW, lb	812	803	5.1	0.24
LM area, in[2]	13.3	13.2	0.10	0.20
Marbling[2]	461	470	6.6	0.38
12th Rib Fat, in	0.47	0.52	0.017	0.05
USDA YG	3.0	3.1	0.07	0.07

[1]Calculated from HCW adjusted to a common 63.0% dress

[2]Marbling score: 400 = Small[00], 500 = Modest[00]

[3]CON = 0 g/hd/d *Aspergillus*

[4]ASP = 10 g/hd/d *Aspergillus*

Results

There were no significant interactions ($P \geq 0.23$) observed between corn processing methods and *Aspergillus* in the diet; therefore, only main effects are presented. For the main effect of *Aspergillus* (Table 2); there were no differences observed for carcass-adjusted final BW, DMI, and ADG leading to no difference in F:G ($P \geq 0.14$) for cattle fed 0 or 10 g/d of *Aspergillus*. There were no differences ($P \geq 0.20$) observed for HCW, LM area or marbling due to *Aspergillus* feeding. Cattle fed *Aspergillus* had a greater amount of 12th rib fat ($P = 0.05$) compared to cattle fed 0 g/d. There was a tendency for cattle fed *Aspergillus* to have a greater USDA YG ($P = 0.07$) compared to cattle fed none.

For the main effects of grain processing, there was an effect of corn processing method on carcass adjusted final BW with steers fed DRC being heavier than steers fed HMC ($P = 0.04$). There also was an effect of processing method on DMI with steers fed DRC eating significantly more than steers fed HMC ($P < 0.01$). Steers fed DRC had a greater ADG than steers fed HMC ($P = 0.05$). However, steers fed HMC had the lower F:G compared to steers fed DRC ($P < 0.01$). There was an effect of processing method on HCW, with steers fed DRC being heavier than steers fed HMC ($P = 0.04$). There was an effect of processing method on ribeye area with steers fed DRC having a larger ribeye area than steers fed HMC ($P = 0.04$). No significant differences were observed for steers fed the different processing methods for initial BW, marbling, 12th rib fat and yield grade ($P \geq 0.13$; Table 2).

Conclusion

Feeding finishing cattle *Aspergillus* in diets with either DRC or HMC did not statistically improve any of the growth performance or carcass characteristics measured. Cattle fed DRC diets had a greater final BW, DMI and ADG compared to cattle fed HMC. However, cattle fed HMC had a 6.25% decrease in F:G compared to DRC diets. These data suggest that feeding *Aspergillus* does not affect F:G for finishing diets containing 25% MDGS. The lower DMI and ADG observed would suggest a potential acidosis problem for cattle fed HMC compared to DRC based finishing diets.

Table 3. Main effect of corn processing method on cattle performance and carcass characteristics

	Corn Processing[3]			
	DRC	HMC	SEM	P-Value
Pens, *n*	8	8	--	--
Initial BW, lb	589	588	0.5	0.13
Carcass-Adjusted Performance				
Final BW, lb[1]	1295	1270	8.1	0.04
DMI, lb/d	22.4	20.4	0.16	< 0.01
ADG, lb[1]	3.58	3.46	0.042	0.05
F:G[1]	6.25	5.88	--	< 0.01
Carcass Characteristics				
HCW, lb	816	800	5.1	0.04
LM area, in^2	13.4	13.1	0.10	0.04
Marbling[2]	466	466	6.6	0.98
12th Rib Fat, in	0.50	0.49	0.017	0.87
USDA YG	3.0	3.1	0.07	0.34

[1]Calculated from HCW adjusted to a common 63.0% dress

[2]Marbling score: 400 = Small^{00}, 500 = Modest^{00}

[3]DRC and HMC included in the diet at 64%, 25% MDGS, 6% Grass Hay, and 5% supplement

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Evaluation of Wheat Blended with Corn in Finishing Diets Containing Wet Distillers Grains

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Summary with Implications

An experiment was conducted to evaluate the effect of grain type and wet distillers grains inclusion on finishing cattle performance and carcass characteristics. It was hypothesized that a greater inclusion of wet distillers grains would help mitigate acidosis previously observed with feeding wheat. Treatments were designed as a 2 × 2 factorial arrangement, with the first factor as grain type at either 100% dry rolled corn or a 50:50 blend of dry-rolled wheat and dry-rolled corn, and the second factor as wet distillers grains plus solubles (WDGS) inclusion at either 12 or 30% of diet dry matter. There were no interactions between grain type and WDGS inclusion level. Increasing WDGS in the diet improved average daily gain and feed conversion and increased hot carcass weight. There was no performance or carcass trait response to grain type. Increasing the inclusion of WDGS in the diet improves performance regardless of grain type used. Contrary to the hypothesis, feeding dry-rolled corn or a blend of dry-rolled corn and dry-rolled wheat performed similarly at different WDGS inclusions, and may be an economical replacement for corn during certain times of the year.

Introduction

Feeding dry-rolled wheat as a grain source in finishing diets is not a new concept, but its rapid ruminal fermentation can cause digestive disturbances, such as acidosis. However, in certain regions and months of the year, wheat may become an economically feasible option to replace corn as part of the diet for beef cattle. Much of the previous work on feeding wheat as part of the diet was done prior to the widespread use of distillers grains in the diet. Many Nebraska feedlots are feeding some level of distillers grains, but performance advantages suggest that yards should be feeding at least 12% but no more than 40% WDGS (DM-basis) as part of the diet. Perhaps, feeding more readily fermentable starch from wheat with 30% WDGS will mitigate acidosis concerns and increase performance compared to lower WDGS levels, such as 12%. Therefore, the objective of this experiment was to compare DRC-based or a 50:50 blend of DRC and wheat-based diets with either 12 or 30% WDGS (DM-basis) on finishing cattle performance and carcass characteristics.

Table 1. Diet composition (% of diet DM) of corn or corn and wheat blended diets with two inclusions of WDGS.

Grain Type	DRC	DRC	BLEND[1]	BLEND
WDGS Inclusion	12	30	12	30
DRC	67	49	33.5	24.5
Wheat	0	0	33.5	24.5
WDGS	12	30	12	30
Corn Silage	15	15	15	15
Supplement[2]	6	6	6	6
Urea	1	0	0.5	0
Chemical Composition, %				
Diet DM	69.38	59.88	70.65	60.89
Crude Protein	13.0	14.7	13.0	15.7
Ca	0.76	0.77	0.77	0.78
P	0.30	0.43	0.35	0.47

[1] 50:50 blend of DRC and wheat

[2]Liquid supplement was 68% DM and formulated to provide: 0 or 1% urea, 10.9% calcium, 390 mg/hd/d monensin, and 83 mg/hd/d tylosin.

Procedure

A feedlot study was conducted at the University of Nebraska—Lincoln Panhandle Research and Extension Center (PREC), Scottsbluff, NE. Crossbred steers (n=320; initial BW = 716 ± 50 lb) were used in a 2 × 2 factorial treatment design with factors consisting of two grain types [dry-rolled corn (DRC) or dry-rolled corn/dry-rolled wheat blend (BLEND)] and two inclusions of wet distillers grains (WDGS) levels (12 or 30% DM-basis or 22.1% or 45.8% as-fed). Corn silage was used as the roughage source in all diets (Table 1). A liquid supplement was fed with either 0% or 1% of urea. The 1% urea supplement was used in the dry-rolled corn with 12% WDGS diet. A 50:50 blend of the 0% and 1% urea supplement was used in the corn-wheat blend with 12% WDGS diet to target 0.5% urea in the diet. No urea was added to diets containing 30% WDGS. Wheat was processed on-site using a roller mill (Automatic Ag, Pender, NE) and corn was processed using a commercial roller mill throughout the feeding study. All cattle were limit fed a common diet consisting of 30% alfalfa hay, 40% corn silage, 25% WDGS, and 5% supplement (DM-basis) for 5 consecutive days to minimize BW variation due to gut

Table 2. Effect of feeding DRC or 50:50 blend of DRC on steer performance and carcass characteristics.

Grain Type	DRC	BLEND	SEM	Grain Type P-Value
Initial BW	716	716	0.7	0.95
Live Performance				
Final BW	1352	1357	6.9	0.58
DMI, lb/d	23.9	24.3	0.29	0.29
ADG, lb	4.02	4.06	0.042	0.56
F:G[1]	5.92	5.99	—	0.59
Carcass Adj. Performance				
Final BW[2]	1325	1327	7.6	0.84
ADG, lb/d	3.85	3.87	0.048	0.81
F:G[1]	6.17	6.29	—	0.43
Carcass Characteristics				
HCW, lb	835	836	4.8	0.84
Dressing %	61.8	61.6	1.7	0.53
REA, in^2	13.1	13.5	0.087	0.02
12th rib fat, in.	0.52	0.50	0.012	0.36
Marbling Score[3]	533	511	10.7	0.15
Calculated YG[4]	3.27	3.13	0.049	0.04
Liver Abscess, %	13.3	14.2	3.9	0.61

[1] Analyzed as its reciprocal, G:F

[2] HCW adjusted to a common dressing percent of 63%

[3] 400 = small, 500 = modest, 600 = moderate

[4] Calculated using the following equation: 2.5 + (2.5*12th rib fat thickness, in.)—(0.32*LM area, in^2) + (0.2*2.5 KPH) + (0.0038*HCW, lb) (USDA, 2016)

fill. Cattle were fed once daily and provided ad libitum access to feed and water. All cattle were stepped up to their respective diet over 23 d with concentrate (corn and/or wheat) replacing alfalfa hay and corn silage (25% and 40%, respectively, for alfalfa hay and corn silage initially). The finishing diet is presented in Table 1. Cattle were weighed two consecutive days to establish initial BW. Three blocks were used with two reps in the light block, four reps in the middle block, and two reps in the heavy block for 32 total pens with 8 replications per treatment (10 steers/pen).

Cattle were implanted with Revalor-XS (200 mg trenbolone acetate + 40 mg estradiol; Merck Animal Health) on d 1. Steers were fed for 158 days and harvested at a commercial abattoir (Greater Omaha Packing, Omaha, NE). On the day of shipping, steers were weighed in the morning, loaded, and shipped to be harvested the following morning. Hot carcass weight and liver score were recorded on harvest date, and LM area, USDA marbling score, and 12th rib back fat were collected following a 48-hour chill using camera data. Final live BW was calculated using the pen average final live BW shrunk 4% to adjust for fill. Carcass-adjusted performance was calculated by dividing hot carcass weight by a common dressing percentage of 63%.

Samples of processed corn and wheat were taken throughout the feeding study and composited for analysis of particle size using dry sieving. Samples were measured in duplicate to determine geometric mean diameter and geometric standard deviation.

Data were analyzed using the mixed procedure of SAS as a 2 × 2 factorial design with main effects of grain type and WDGS inclusion and the appropriate interactions. Block, grain type and WDGS inclusion were considered fixed effects. Liver data were analyzed using the GLIMMIX procedure of SAS as a binomial distribution. Alpha values ≤ 0.05 were considered significant and 0.05 ≤ α ≤ 0.10 is considered a tendency.

Results

There were no significant interactions between grain type or WDGS inclusion ($P \geq 0.21$). Average daily gain was 3.80, 3.91, 3.78 and 3.96 lb/d and F:G was 6.29, 6.06, 6.41 and 6.13 for DRC12, DRC30, BLEND12 and BLEND30, respectively. The hypothesis that wheat blended with corn would result in better gain and feed conversion in diets with 30% WDGS compared to 12% WDGS was not correct. Due to the lack of an interaction of grain type and WDGS inclusion, only main effects will be discussed. There were no differences in live or carcass-adjusted final BW, ADG, DMI, or feed conversion ($P \geq 0.29$; Table 2) between 100% DRC or 50:50 blend of DRC and wheat. Geometric mean diameter of DRC was 3814 µm (SD = 1201 µm) and DRW was 2258 µm (SD = 432 µm). These data suggest that up to 50% wheat can be fed as the grain portion of the diet resulting in no change in performance.

Steers that were fed 30% WDGS were 24 lbs heavier ($P = 0.03$; Table 3) at slaughter as compared to steers fed 12% WDGS. Cattle fed 30% WDGS had improved ADG by 3.8% ($P = 0.03$) and were 3.8% more efficient ($P = 0.05$) than steers fed 12% WDGS regardless of grain type.

There were no significant interactions between grain type and WDGS inclusion ($P \geq 0.32$) for carcass characteristics, therefore, only the main effects of grain type and WDGS inclusion will be presented. There was no difference in HCW or dressing percent ($P \geq 0.53$; Table 2) for steers fed 100% DRC or 50:50 blend of DRC and wheat. Longissimus muscle area was significantly greater ($P = 0.02$) for steers fed 50:50 blend of DRC and wheat compared to steers only fed DRC. No differences were observed in 12th rib fat or USDA marbling score between grain type ($P \geq 0.15$), but with the increase in LM area, cattle fed the blended diet had an improved calculated yield grade ($P = 0.04$). It is important to note that this

Table 3. Effect of WDGS inclusion level on performance and carcass characteristics of finishing steers.

WDGS Inclusion	12	30	SEM	WDGS Incl. P-Value
Initial BW	719	719	0.7	0.51
Live Performance				
Final BW	1345	1364	6.9	0.06
DMI, lb	24.1	24.1	0.29	0.93
ADG, lb/d	3.98	4.10	0.043	0.07
F:G[1]	6.02	5.88	—	0.07
Carcass Adj. Performance				
Final BW[2]	1314	1338	7.6	0.03
ADG, lb/d	3.79	3.94	0.048	0.03
F:G[1]	6.37	6.10	—	0.05
Carcass Characteristics				
HCW, lb	828	843	4.8	0.03
Dressing %	61.6	61.8	1.7	0.28
REA, in^2	13.2	13.4	0.09	0.13
12th rib fat, in.	0.49	0.53	0.013	0.02
Marbling Score[3]	531	513	10.7	0.24
Calculated YG[4]	3.14	3.26	0.049	0.09
Liver Abscess, %	11.3	12.7	3.5	0.42

[1] Analyzed as its reciprocal, G:F

[2] HCW adjusted to a common dressing percent of 63%

[3] 400 = small 00; 500 = modest 00; 600 = moderate 00

[4] Calculated using the following equation: 2.5 + (2.5*12th rib fat thickness, in.)—(0.32*LM area, in^2) + (0.2*2.5 KPH) + (0.0038*HCW, lb) (USDA, 2016)

was a heavily replicated study (16 replications per main effect) and therefore, small changes were statistically significant and may not be explained biologically.

Steers fed 30% WDGS had heavier HCW ($P = 0.03$; Table 3), had greater 12th rib fat ($P = 0.02$), and tended to have poorer yield grade ($P = 0.09$) compared to cattle fed 12% WDGS. There were no differences between WDGS inclusions for dressing percent, LM area, or USDA marbling score ($P \geq 0.13$).

Conclusion

Overall, there was no interaction between grain type (DRC or 50:50 blend DRC and wheat) and WDGS inclusion (12 or 30% DM basis) for cattle performance or carcass characteristics. There was a significant response for cattle fed 30% WDGS compared to 12% WDGS, but there was no performance response for grain type. Feeding a 50:50 blend of DRC and wheat resulted in an increase in LM area and no change in other carcass characteristics, leading to a more desirable calculated YG. Greater inclusions of WDGS (30%) resulted in greater HCW and 12th rib fat but tended to increase calculated YG compared to feeding 12% WDGS. There were minimal effects to feeding DRC compared to a 50:50 blend of DRC and wheat, but there was a performance and carcass response to feeding more WDGS. Therefore, the data suggest that if the price of wheat is competitive or less than that of corn, wheat can replace up to 50% of corn in the diet, regardless of WDGS inclusion, without an effect on performance.

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Evaluation of Condensed Algal Residue Solubles as an Ingredient in Cattle Finishing Diets

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Summary with Implications

A study was conducted to evaluate feeding 0, 2.5, or 5.0% of a novel liquid feed, Condensed Algal Residue Solubles (CARS), in one of two base diets with CARS replacing corn. The two base diets were fed to mimic Northern Great Plains (high moisture and dry rolled corn blend fed with wet distillers grains plus solubles) and Southern Great Plains (steam-flaked corn and dry distillers grains plus solubles) feedlot diets. There were no interactions between base diet and CARS inclusion. Feed intake and longissimus muscle area decreased as CARS inclusion increased in the diet. A quadratic effect was shown for average daily gain, feed efficiency, final adjusted body weight, hot carcass weight, 12th rib fat, and yield grade, increasing as CARS was included up to 2.5% of diet dry matter, then decreased at 5% inclusion. Marbling score improved with increased inclusion of CARS, with the highest score at 5% CARS inclusion. Including CARS at 2.5% of diet dry matter improved feed efficiency in both Northern and Southern Great Plains diets.

Introduction

Mass production of algae to harvest eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) Omega-3 fatty acids involves growing algae with sugars, then processing the cells to separate and remove the oil for the Omega-3 supplements as feed for pets and aquaculture. The liquid biproduct from this process is known as Condensed Algal Residue Solubles (CARS; 25.4% DM, 19.3% CP, 8.3% Fat, 9.96% Na on DM basis; Table 1), made up of the deoiled algae cells and residual fermentation substrates. In a previous study, CARS was included up to 7.5% of diet DM and had no adverse effect on cattle with improved performance when fed up to 5.0% of diet DM (*2019 Nebraska Beef Cattle Report*, pp. 82–84). From this previous study, CARS was granted GRAS (generally recognized as safe) status and has become commercially available (Veramaris, Blair, NE). The objective of this study was to determine the feeding value of CARS in feedlot finishing diets that represent Northern and Southern Great Plains finishing diets.

Procedure

Crossbreed steers (n = 480; initial BW = 951 lb; SD 84 lb) were blocked and stratified by initial BW into 4 blocks and assigned randomly to pens (n = 48) after the first day of weight collections. Pens were assigned randomly to treatment. Treatments were designed as a 2 × 3 factorial with 3 inclusions of CARS (0, 2.5, 5% of diet DM) in 2 base diets representing Northern and Southern Great Plains diets (Table 2). All diets included a 4% dry meal supplement containing Rumensin-90 (fed to target 30 g/ton of diet DM, Elanco Animal Health) and Tylan-40 (fed to target 90 mg/hd/d, Elanco Animal Health), along with trace minerals, vitamins ADE, tallow, calcium, salt (not included in the 5% CARS diets) and 0.5 % urea to ensure RDP requirements were met. Diets were formulated to provide similar Ca and appropriate Ca:P ratios. Southern diets contained steam flaked corn (SFC) and 15% dry distillers grains (DDGS) while the Northern diets contained dry rolled (DRC) and high moisture corn (HMC) with 15% wet distillers grains (WDGS). The CARS feed is a liquid and replaced either DRC/HMC or SFC in the diets.

All steers were limit fed at 2% of body weight for 5 days prior to the start of the trial using 50% alfalfa and 50% Sweet Bran (Cargill, Blair, NE) as a common diet to minimize differences in gut fill. Steers were then weighed on two consecutive days before feeding to calculate average initial weight. Steers were implanted on d 1 with Revalor-IS (80 mg trenbolone acetate and 16 mg estradiol, Merck Animal Health) and on d 70 were re-implanted with Revalor-200 (200 mg trenbolone acetate and 20 mg estradiol, Merck Animal Health). On d 120 to d 148 Optaflexx (Elanco Animal Health) was included in the diet at 300 mg/hd daily. Feed refusals were collected as needed throughout the trial and analyzed for DM in order to adjust feed offered to actual dry matter intake (DMI).

All blocks were harvested after 148 days on feed. Hot carcass weight (HCW), liver abscess scores, and kill order were recorded. Carcass adjusted final body weights (BW) were calculated from HCW and a common 63% dressing percentage. Carcass adjusted

Table 1. Nutrient composition of CARS and FAME analysis (DM basis)

Item	CARS[1]
Dry Matter (DM), %	25.43
Dry Basis	
Crude Protein	19.30
Fat (Oil)	15.05
DHA	6.25
EPA	1.98
Calcium	0.44
Magnesium	0.45
Phosphorus	0.53
Potassium	0.80
Sulfur	3.05
Sodium	9.96
ppm, DM Basis	
Zinc	55.4
Iron	168
Manganese	13
Copper	8.2
Molybdenum	1.18

[1] Nutrient Composition of CARS was analyzed by Ward Laboratories, Inc. (Kearney, NE)

[2] DHA and EPA analyzed by Veramaris (Blair, NE)

Table 2. Dietary treatment compositions (DM basis) for finishing steers fed increasing inclusion of CARS in Northern or Southern Great Plains based diets

	Northern			Southern		
Ingredient, % diet DM	0%	2.5%	5%	0%	2.5%	5%
Dry Rolled Corn	36.5	35.25	34	-	-	-
High Moisture Corn	36.5	35.25	34	-	-	-
Wet Distillers Grains	15	15	15	-	-	-
Steam Flaked Corn	-	-	-	73	70.5	68
Dried Distillers Grains	-	-	-	15	15	15
CARS	0	2.5	5	0	2.5	5
Alfalfa Haylage	8	8	8	8	8	8
Supplement[1]	4	4	4	4	4	4

[1] Rumensin fed at 30 g/ton (DM); Tylan fed to target 90 mg/hd/d

final body weight was used to calculate average daily gain (ADG) and feed to gain (F:G). Dietary NEm and NEg values were calculated utilizing initial BW, adjusted final BW, BW at target endpoint (heaviest pen average BW by block), ADG and DMI. Carcass characteristics including marbling score, 12th rib back fat thickness, longissimus muscle (LM) area, and yield grade were recorded after a 48 hour chill.

Economic analysis of CARS, as feed cost of gain, was modeled with the assumptions that CARS was equal to the cost of corn, and Northern Great Plains and Southern Great Plains base diet costs were averaged together. Corn costs used were $3.00, $3.50, $4.00, and $4.50/bushel with equivalent costs at $0.06, $0.07, $0.08, $0.10/lb of DM. Results of this analysis are reported as feed cost of gain/cwt body weight gained.

Performance data were analyzed using the PROC MIXED procedure of SAS (SAS institute, Inc., Cary, N.C.) as a 2×3 factorial. CARS inclusion, base diet, the interaction between CARS and base diet, and body weight block were included as fixed effects. Pen was the experimental unit. Orthogonal contrasts were used to test linear and quadratic effects of CARS inclusion. If no interaction was detected, the main effects of CARS inclusion and base diet were evaluated and are presented.

Results

One steer died from bloat during the study and two others were removed (i.e. dislocated shoulder, heart and liver issues) There were no significant interactions between CARS inclusion and diet type ($P \geq 0.49$) for any variable tested. Therefore, main effects are discussed.

CARS inclusion main effects

Increasing inclusion of CARS resulted in a linear decrease ($P < 0.01$) in DMI. There was a positive quadratic response for ADG ($P < 0.01$), with 0% and 2.5% CARS having similar ADG and decreasing at the 5% CARS inclusion. This resulted in a quadratic response for F:G ($P < 0.01$) as CARS inclusion in the diet increased with 2.5% CARS inclusion having the lowest F:G with a 4.3% improvement compared to the control and 5% CARS treatment having the greatest F:G. There was a positive quadratic response for both NEm and NEg ($P < 0.01$), with 0% and 5% CARS having similar values and 2.5% CARS having the greatest value. Both carcass adjusted final BW and HCW had positive quadratic responses ($P < 0.01$) as CARS inclusion increased in the diet, with final body weights and HCW being the heaviest at the 2.5% inclusion level. Longissimus muscle area linearly decreased ($P < 0.01$) with increasing inclusion of CARS. Measures of 12th rib fat thickness showed a positive quadratic response ($P < 0.01$) with maximum 12th rib fat at 2.5% CARS inclusion and 5% CARS having the least. Marbling score linearly increased ($P < 0.01$) from 563 with 0% CARS to 598 with 5% CARS, but all treatments averaged choice grade. Yield grade had a positive quadratic response ($P < 0.01$), with a maximum yield grade observed at the 2.5% CARS inclusion, while 0% and 5% CARS inclusion had similar grades.

Main effects of diet

Main effects of diet indicated that DMI for both Northern and Southern Plains were similar ($P = 0.72$). Southern diets had greater ADG compared to Northern diets ($P < 0.01$) and F:G was 5.9% greater for Southern compared to Northern diets ($P < 0.01$). Steam-flaked corn diets commonly increase feed efficiency by 12% compared to dry rolled corn diets. The improved efficiency measured in this trial was only half that amount, likely due to differences between dry and wet distillers grains in these diets. Dietary NEm and NEg were different between base diets ($P < 0.01$), with Southern diets having greater energy concentration than Northern diets due to the SFC in the Southern diets. Steers fed the Southern diets had greater carcass adjusted final body weights and improved HCW compared to steers fed the Northern diets ($P < 0.01$). The longissimus muscle area was statistically similar for both diets ($P = 0.09$) while 12th rib fat thickness and YG were greater for Southern diets compared to the Northern ($P = 0.02$). Marbling scores were not statistically different ($P = 0.06$) but Southern diets had numerically greater scores compared to the Northern diets.

Economic Analysis

Economics are reported as feed cost of gain/cwt final body weight gain. In each scenario of different corn prices there was a quadratic decrease in feed cost of gain as CARS inclusion increased in the diet ($P < 0.01$). For all scenarios, 2.5% CARS inclusion had the lowest feed cost of gain. As corn price (feed costs) increased, the average savings increased from $1.74/cwt for 2.5% CARS compared to 0% CARS at $3/bu corn up to $2.60/cwt at $4.50/bu corn cost. Similarly, the average loss incurred also increased from $0.54/cwt to $0.81/cwt for the 5% CARS treatment compared to 0% CARS as corn cost increased from $3/bu to $4.50/bu. Therefore, if CARS can be purchased, delivered, and fed for similar costs as corn,

Table 3. Main effects of CARS inclusion on growth performance and carcass characteristics

	Treatment[1]				*P*-value[2]		
Item	CON (0)	2.5	5	SEM	*CARS*	*Linear*	Quadratic
Performance							
Initial BW, lb	951	951	951	0.8	0.81	0.55	0.80
Final BW, lb[3]	1566[a]	1576[a]	1504[b]	8.9	<0.01	<0.01	<0.01
DMI, lb/d	26.2[a]	25.5[b]	23.9[c]	0.256	<0.01	<0.01	0.05
ADG, lb[3]	4.15[a]	4.22[a]	3.74[b]	0.061	<0.01	<0.01	<0.01
Feed to Gain	6.32[a]	6.05[b]	6.41[a]	0.085	<0.01	0.32	<0.01
NEm, Mcal/lb	0.89[a]	0.92[b]	0.89[a]	0.018	<0.01	0.66	<0.01
NEg, Mcal/lb	0.59[a]	0.62[b]	0.59[a]	0.017	<0.01	0.70	<0.01
Carcass Characteristics							
HCW, lb	986[a]	993[a]	948[b]	5.5	<0.01	<0.01	<0.01
LM area, in[2]	15.0[a]	14.8[a]	14.3[b]	0.16	<0.01	<0.01	0.28
12th Rib Fat, in	0.63[a]	0.67[b]	0.61[a]	0.016	<0.01	0.21	<0.01
Marbling Score[4]	563[a]	579[ab]	597[b]	10.4	<0.01	<0.01	0.88
Yield Grade	3.57[a]	3.67[b]	3.51[a]	0.038	<0.01	0.20	<0.01

[a,b] Means within a row that lack a common superscript differ ($P < 0.05$)

[1] Treatments were arranged as a 2×3 factorial and included CARS at 0, 2.5, and 5% of diet DM in both Northern and Southern Great Plains diets

[2] Main effects included CARS inclusion in the diet and diet type (Northern or Southern Great Plains). The interaction between diet and CARS was not significant for any variable measured ($P \geq 0.49$). Linear and quadratic orthogonal contrasts are shown for CARS inclusion in the diet

[3] Calculated from hot carcass weight, adjusted to a common 63% dressing percentage

[4] Marbling Score 400-Small00, 500 = Modest00

Table 4. Main effects of base diets on growth performance and carcass characteristics

	Treatment[1]			
Item	Northern	Southern	SEM	*P*-value[2]
Performance				
Initial BW, lb	951	951	0.8	0.71
Final BW, lb[3]	1531	1566	8.9	< 0.01
DMI, lb/d	25.2	25.1	0.256	0.72
ADG, lb[3]	3.92	4.16	0.061	< 0.01
Feed to Gain	6.45	6.07	0.085	< 0.01
NEm, Mcal/lb	0.88	0.92	0.008	< 0.01
NEg, Mcal/lb	0.58	0.62	0.017	< 0.01
Carcass Characteristics				
HCW, lb	965	987	5.5	< 0.01
LM area, in[2]	14.6	14.8	0.16	0.09
12th Rib Fat, in	0.62	0.65	0.016	0.02
Marbling Score[4]	572	588	10.4	0.06
Yield Grade	3.54	3.62	0.038	0.01

[1] Treatments were arranged as a 2×3 factorial and included CARS at 0, 2.5, and 5% of diet DM in both Northern and Southern Great Plains diets

[2] *P*-value for the main effects of base diet

[3] Calculated from hot carcass weight, adjusted to a common 63% dressing percentage

[4] Marbling Score 400-Small00, 500 = Modest00

small improvements in economics would be expected at the 2.5% diet inclusion.

Conclusions

Including CARS at 2.5% of diet DM improved feed efficiency and hot carcass weight compared to a 0% CARS control diet. There were no interactions between type of diet (Northern and Southern Great Plains feedlot diets) and CARS inclusion (0, 2.5, and 5% of diet DM). There was greater feed efficiency and hot carcass weight in Southern diets compared to the Northern base diets. Feeding 2.5% CARS reduced feed cost of gain.

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Effects of Butyrate in Finishing Cattle Diets

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Summary with Implications

Butyrate is produced in the rumen as an end product from fermentation and is an important energy source for epithelial tissue. In a corn based finishing cattle diet ruminally protected butyrate (Ultramix-C) was supplemented at 0.3% of diet dry matter while a ruminally unprotected butyrate product (MiruTyton) was fed at 1% of the diet, with both compared to a common control diet (0% butyrate). There were no differences in dry matter intake among treatments. There were also no differences in final body weight, daily gain, feed efficiency, and hot carcass weight. There was a significant difference in ribeye area with cattle consuming the butyrate diets having greater ribeye area (15.8 in^2) than control cattle (14.4 in^2). While interim weights suggest feeding butyrate early in the feeding period may hold some benefit for young or newly weaned calves, there is no clear benefit throughout the feeding period.

Introduction

Butyrate is a short-chain fatty acid that is produced by microbial fermentation in the large intestine as well as the rumen of ruminant animals. It has been shown to enhance gut development, reduce inflammation, improve growth performance and help control enteric pathogens in the rumen when fed to young growing calves. Butyrate can also improve rumen epithelium development which can improve animal performance, especially early on in life. Butyrate is commonly added to milk replacers and colostrum in early weaned calf diets to increase rumen papillae development. However, feeding butyrate to finishing steers is not common as butyrate is already produced in the rumen of these mature animals. The benefits of butyrate are primarily observed in the lower GI tract. In ruminant animals, protecting these butyrate products from absorption or metabolism in the rumen may be necessary. Therefore, 2 butyrate products were used, a ruminally protected butyrate product at 0.3% of diet DM (Ultramix-C, Nutriad-Adisseo, Alpharetta, GA) and an unprotected butyrate product at 1% of diet DM (MiruTyton, White Dog Labs, Inc., New Castle, DE). The objective was to determine if butyrate is beneficial in finishing cattle diets.

Table 1. Dietary treatment compositions for finishing steers fed rumen protected or unprotected butyrate

Ingredient, % of DM	Control	Ultramix C[1]	MiruTyton[2]
Grass Hay	7	7	7
Modified Distillers Grains plus Solubles	20	20	20
Dry rolled corn	34.5	34.2	33.5
High moisture corn	34.5	34.5	34.5
Unprotected butyrate	0	0	1.0
Protected butyrate	0	0.3	0
Supplement[1]	4	4	4

[1] Ultramix C is a rumen protected butyrate source (Nutriad-Adisseo, Alpharetta, GA)

[2] MiruTyton is a rumen unprotected butyrate source (White Dog Labs, Inc., New Castle, DE)

[3] Supplement contained 1.37% fine ground corn, 1.64% limestone, 0.10% tallow, 0.50% urea, 0.30% salt, 0.05% trace mineral, 0.015% Vitamin ADE, rumensin (30 g/ton), and tylan (8.9 g/ton).

Procedure

A 141-d finishing study was conducted at the University of Nebraska Research and Extension Center near Mead, NE using 30 crossbred yearling steers (initial body weight (BW) = 877 lb.). Prior to this trial, cattle were backgrounded on corn residue through the winter months, until start of the trial in May. Steers were limit fed a diet consisting of 50% alfalfa hay and 50% Sweet Bran (Cargill corn milling, Blair, NE) for five days prior to trial initiation at 2% of BW to reduce gut fill variation. Steers were then weighed 3 consecutive days to establish average initial BW. Steers were stratified by BW and assigned randomly to one of 3 treatments (control, protected butyrate at 0.3% of diet DM, and unprotected butyrate at 1% of diet DM). Treatment diets are presented in Table 1. The diets consisted of a 50:50 blend of dry rolled corn and high moisture corn with 7% grass hay and 20% modified distillers grains plus soluble. Rumensin and Tylan (Elanco Animal Health, Greenfield, IN) were included in all diets. The butyrate products were added to the feed truck as an ingredient at the time of feeding and replaced dry rolled corn in the diet. All steers were individually fed using the Calan gate system.

Steers were implanted on d-1 with Revalor-IS and re-implanted on d-57 with Revalor-200 (Merck Animal Health, Summit, NJ). Interim individual cattle body weights were taken on days 30, 56 and 57 of the trial. Cattle were fed ad libitum once daily. Feed refusals were collected weekly, weighed, and dried in 60° C forced air oven for 48 hours to calculate accurate DMI for individual steers.

Steers were fed for 141 days prior to harvest. Cattle from all treatments were individually weighed on 3 consecutive days at

Table 2. Effects of rumen protected and unprotected butyrate on cattle performance and carcass characteristics

	Control	Ultramix C[1]	MiruTyton[2]	SEM	*P*- Value
Initial BW, lb	878	879	868	23.1	0.94
Live Performance					
Final BW, lb	1422	1415	1411	32.0	0.97
Dry Matter Intake, lb/d	24.4	24.8	24.7	0.69	0.89
Daily Gain, lb	3.86	3.65	3.70	0.12	0.44
Feed:Gain	6.29[a]	6.80[b]	6.67[b]	—	0.10
Carcass Adjusted Performance					
Final BW[3], lb	1420	1453	1431	30.5	0.74
Daily Gain, lb	3.85	3.90	3.83	0.12	0.90
Feed:Gain	6.29	6.33	6.41	—	0.84
Dressing Percentage, %	62.9[a]	64.7[b]	64.0[b]	0.50	0.04
Hot Carcass Weight, lb	895	916	902	19.2	0.74
Ribeye Area, in^2	14.4[a]	15.8[b]	15.8[b]	0.35	0.01
12th Rib Fat, in	0.63	0.66	0.64	0.04	0.89
Marbling	478	501	509	19.1	0.50

[1] Ultramix C is a rumen protected butyrate source (Nutriad-Adisseo, Alpharetta, GA)

[2] MiruTyton is a rumen unprotected butyrate source (White Dog Labs, Inc., New Castle, DE)

[3] Harvest was done at a commercial abattoir for the Control treatment and across 12 days at the UNL Meat Science Lab for the Ultramix-C and MiruTyton treatments which may have influenced carcass adjusted performance.

Table 3. Interim cattle performance

	Control	Ultramix C[1]	MiruTyton[2]	SEM	*P*- Value
Initial BW, lb	878	879	868	23.1	0.94
Day 30 performance					
Body weight, lb	1006	1020	1004	24.1	0.88
Daily gain, lb	4.44	4.87	4.69	0.15	0.12
Dry Matter Intake, lb/d	24.2	25.2	24.7	0.51	0.39
Feed:Gain	5.41	5.16	5.24	—	0.59
Day 57 performance					
Body weight, lb	1137	1128	1122	26.8	0.92
Daily gain, lb	4.64	4.46	4.53	0.17	0.75
Dry Matter Intake, lb/d	25.5	25.9	25.5	0.72	0.91
Feed:Gain	5.46	5.81	5.62	—	0.51

[1] Ultramix C is a rumen protected butyrate source (Nutriad-Adisseo, Alpharetta, GA)

[2] MiruTyton is a rumen unprotected butyrate source (White Dog Labs, Inc., New Castle, DE)

the conclusion of the feeding period. Cattle from the control treatment were loaded on trucks in the afternoon of d-141 after feeding 50% of the previous day's intake. These cattle were then harvested at a commercial abattoir the following morning. The two butyrate products were not FDA approved to be fed to cattle; therefore, cattle on those treatments were composted. The cattle fed the butyrate products were harvested across 12 days (starting on d-142) at the University of Nebraska Meat Science Lab (5 animals per day and 4 harvest dates). For all treatments, on the day of harvest kill order, liver abscess scores and HCW were recorded and carcass- adjusted BW was calculated from a common 63% dressing percentage. Carcass characteristics included marbling score, longissimus muscle area and yield grade, were recorded after a 48-hour chill.

Data were analyzed using the GLIMMIX procedure of SAS as a randomized design. Steer was the experimental unit and treatment was a fixed effect. Treatment means were compared when the F-statistic for treatment was significant. Significance was declared at $P \leq 0.05$ and tendencies at $P \leq 0.10$.

Results

Performance results are presented in Table 2. There were no significant differences observed for DMI (dry matter intake), ADG (average daily gain), and final BW among the treatments ($P \geq 0.44$). Live feed:gain tended ($P = 0.10$) to be improved for the control (6.29) compared to the butyrate supplemented diets (6.73); however, there were no differences in carcass adjusted feed:gain ($P = 0.84$). Hot carcass weight was not different among treatments ($P = 0.74$). The different harvest procedures used for the butyrate treatments compared to the control did result in differences in dressing percentages ($P = 0.04$), 62.9% for CON and 64.4% for the butyrate treatments. This was likely due to harvest method (cattle fed the

butyrate products could not be harvested at a commercial abattoir) and not related to treatment. Marbling and 12th rib fat were not different between treatments ($P \geq 0.50$). Ribeye area was larger for both butyrate treatments (15.8 in^2) compared to the control (14.4 in^2; $P = 0.01$).

Interim performance suggests there may be benefits of butyrate supplementation early in the feeding period (Table 3). After the first 30 days on feed there were no differences in DMI ($P = 0.39$) and a tendency for an improvement in ADG ($P = 0.12$), with a 7.5% increase for butyrate supplemented treatments. Similar to final performance, there were no differences observed on day 57 ($P \geq 0.51$). Day 30 performance is based on a 1-day body weight measurement while body weights were measured on 2 consecutive days for the day 57 performance. Yearling cattle that had undergone a backgrounding period were used for this study. Different results may be observed for newly weaned calves, especially during the step up period going from a forage based to concentrate based finishing diet when rumen and gut health are critical.

Conclusion

Supplementation of butyrate had limited effects on yearling cattle performance in a finishing diet. Both ruminally protected and unprotected butyrate increased ribeye area. Feeding butyrate to finishing cattle at different inclusion levels or at targeted times during the feeding period may result in different results. Butyrate may be more beneficial in young cattle diets, with evidence of improved performance due to rumen and gut development for bottle-fed and newly weaned calves.

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Impact of Days Fed on Holstein Bull and Steer Performance and Cutability of Cattle Pen-Fed Organic Diets

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Summary with Implications

Performance, carcass characteristics, and total meat yield of Holstein bulls and steers were compared in a simulated organic production system with the goal of producing ground beef. Holstein bulls (n = 120, initial BW = 487 lb) and steers (n = 120, initial BW = 471 lb) of the same age were blocked by BW and assigned randomly to be harvested at 308, 343, 378, and 413 days on feed. After harvest, all meat off the carcass was considered trim and was collected and weighed to calculate total trim yield. Bulls gained faster and had greater live body weight, carcass weight, and trim yield than steers. Steers showed greater linear increases in marbling scores and fat composition of trim yield as days on feed increased than bulls. Increasing days on feed linearly increased feed intake, live body weight, carcass weight, and trim yield. Bulls had greater feed costs per animal than steers but castration had no effect on feed cost of gain. Feed cost per pound of trim yield increased linearly as days on feed increased. Feeding bulls may increase profitability in a ground beef production system that is not penalized for low quality beef.

Introduction

The use of steroidal hormones in beef cattle production has been approved since the 1950s. Use of a hormonal implant can increase average daily gain (ADG) and feed efficiency by up to 20% and 13.5%, respectively. This is due to the anabolic effect steroidal hormones like estrogen and testosterone or synthetic analogues of those compounds have on muscle tissue. However, use of hormonal implants and other growth promoting technologies are banned in an organic beef production system. To compensate for the loss of technology and therefore a loss in performance, one option may be to leave male calves intact. When compared to steers, bulls have greater hot carcass weight (HCW) and longissimus muscle (LM) area but less tender meat and reduced marbling scores.

The hypothesis was that bull calves would have increased muscle mass thereby increasing body weight (BW), ADG, and LM area compared to steers and that both steers and bulls would have increased final live BW, hot carcass weight (HCW), and LM area as the length of the feeding period increased. The objective of this study was to compare the performance, carcass characteristics, and total meat yield of Holstein bulls and steers fed an increasing number of days in a simulated organic production system.

Table 1. Diets fed to Holstein bulls and steers in five phases to simulate an organic production system

	Feeding Phase				
Ingredient, %DM	d 1 to d 63	d 64 to d 126	d 127 to d 189	d 190 to d 252	d 253 to Harvest
Dry Rolled Corn	31.0	40.0	53.0	60.2	65.0
Alfalfa Haylage	30.0	30.0	30.0	30.0	30.0
Fish Meal	4.0	3.0	2.0	0.8	0.0
Field Peas	30.0	22.0	10.0	4.0	0.0
Supplement[1]	5.0	5.0	5.0	5.0	5.0

[1]Supplement consisted of fine ground corn carrier with trace minerals, vitamins A-D-E, and limestone

Procedure

Holstein bulls (n = 120, initial BW = 487 lb, SD = 35.3) and steers (n = 120, initial BW = 471 lb, SD = 26.5) were fed at the research feedlot at the Eastern Nebraska Research, Extension, and Education Center (ENREEC) located near Mead, NE. All calves were born at dairies in IA, were similar in age, and were grown at the same facility in South Dakota after weaning until study initiation. Calves were assigned to be castrated or left intact by the preweaning facility that raised them by castrating every other animal in the group. Calves assigned to castration were castrated using elastic bands at 4 wk of age and were weaned off of milk at 8 wk of age. Cattle were processed upon arrival and were given an individual identification number. Calves were vaccinated with the combination intranasal vaccine Inforce 3 (Zoetis), One Shot BVD (Zoetis), Ultrabac-7/Somubac (Zoetis), and injectable doramectin (Dectomax, Zoetis).

Bulls and steers were blocked by BW into three blocks and assigned randomly to be harvested at 308, 343, 378, and 413 days on feed (DOF). The initial harvest date of 308 DOF was selected to achieve a minimum live BW of 1100 lb, and successive harvest dates were spaced at 35 d intervals. Cattle were housed in earthen pens with 10 calves per pen. Treatments were arranged in a 2 × 4 factorial with castration status and DOF, with each of the three BW blocks represented once for bulls and steers within each assigned harvest date.

Before trial initiation, cattle were limit-fed a diet of 50% alfalfa hayage and 50% Sweet Bran (Cargill) at 2% of BW from d -4 to d 0 to reduce variation in gut fill. Cattle were then weighed on d 0 and d 1 of the study in the morning before feeding and those weights were averaged to determine initial BW. Final live BW was collected

Table 2. Simple effects of castration and days on feed on performance and carcass characteristics of Holstein bulls and steers fed a common diet for different days

	Steers				Bulls					*P*-Value[2]				
Item	308[1]	343	378	413	308	343	378	413	SEM	CAST	L	Q	L int	Q int
No. of animals (pens)	30(3)	30(3)	28(3)	30(3)	28(3)	26(3)	28(3)	30(3)	-	-	-	-	-	-
Initial BW, lb	474	472	473	472	484	490	485	488	3.6	<0.01	0.78	0.87	0.61	0.77
DMI, lb/d	20.1	19.7	20.3	20.6	20.9	20.8	21.4	22.6	0.58	<0.01	0.05	0.25	0.36	0.73
DMI, % of average BW[3]	2.49	2.42	2.40	2.33	2.49	2.40	2.40	2.41	0.041	0.44	<0.01	0.16	0.24	0.52
Live Performance														
Final BW, lb	1138	1153	1253	1301	1188	1250	1310	1383	25.5	<0.01	<0.01	0.55	0.73	0.77
ADG, lb/d	2.16	1.98	2.06	2.01	2.29	2.22	2.19	2.17	0.066	<0.01	0.09	0.38	0.97	0.81
F:G	9.26	9.90	9.80	10.31	9.09	9.35	9.80	10.42	-	0.31	<0.01	0.97	0.35	0.52
Carcass Characteristics														
Hot Carcass Weight, lb	638	659	727	754	685	725	738	796	20.3	0.01	<0.01	0.68	0.60	0.86
Dressing Percentage, %	56.1	57.1	58.0	58.0	57.6	58.0	56.3	57.5	0.81	0.96	0.37	0.91	0.12	0.44
Marbling Score[4]	433	485	479	549	336	345	342	357	15.2	<0.01	<0.01	0.59	0.01	0.81
Fat Depth, in	0.17	0.16	0.19	0.20	0.08	0.06	0.06	0.07	0.014	<0.01	0.24	0.19	0.17	0.73
LM Area, in^2	9.3	9.4	10.4	10.4	11.5	12.1	12.3	12	0.36	<0.01	0.01	0.37	0.26	0.45
Calculated Yield Grade	2.7	2.7	2.7	2.8	1.9	1.8	1.8	2.1	0.09	<0.01	0.11	0.07	0.53	0.25
Trim Yield, lb/animal	460.5	460.1	513.5	532.5	483.5	527.6	530.1	584.8	18.05	<0.01	<0.01	0.56	0.75	0.86
Trim Yield, % of HCW	72.2	69.7	70.6	70.6	70.8	72.7	71.8	73.4	0.91	0.05	0.61	0.46	0.09	0.31
Trim Fat, %	8.8	12.0	15.8	15.2	8.1	7.5	7.8	5.7	1.60	<0.01	0.35	0.19	0.01	0.77
Trim Lean, %	91.2	88.0	84.2	84.8	92.0	92.5	92.2	94.3	1.60	<0.01	0.35	0.19	0.01	0.77
Trim Fat, lb/animal	40.4	57.8	81.0	80.2	37.3	40.3	40.0	33.0	10.49	<0.01	0.05	0.29	0.02	0.75
Trim Lean, lb/animal	428.3	402.3	432.5	452.3	433.7	487.3	490.1	551.9	25.93	<0.01	<0.01	0.41	0.10	0.55

[1]Average days on feed

[2] CAST = castration status; L = linear response for main effect of days on feed (DOF), Q = quadratic response for main effect of DOF, L int = linear interaction between castration status and linear DOF, Q int = quadratic interaction between castration and quadratic DOF

[3]This was calculated as the average lb of DMI over the feeding period divided by the average Live BW over the feeding period

[4]Marbling Score: 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}

using a pen scale, shrunk 4%, and averaged over the number of animals in the pen. Final live BW was calculated only using the weights of the pens that were scheduled to harvest in that event. Final BW was used to calculate average daily gain (ADG).

All cattle were fed a common diet with 30% alfalfa haylage and 5% supplement with dry rolled corn, field peas, and fish meal included at differing proportions to meet metabolizable protein requirements as BW increased over time (Table 1). The supplement was a dry meal with fine ground corn as a carrier and contained limestone, salt, vitamins A-D-E, and trace minerals. Feeds were conventionally grown and processed; however, the diet was designed to mimic the requirement of organic beef production where grazed forage needs to be a minimum of 30% of diet dry matter during the grazing season. In this study, cattle were fed in pens and forage maintained at 30% of diet DM to represent a worst-case scenario of cattle requiring delivered feed year-round. Feed was delivered once daily and feed refusals were collected as needed, weighed, and a subsample was dried in a forced-air oven at 60°C for 48 h to calculate dry matter refusals and accurately estimate dry matter intake (DMI).

Table 3. Simple effects of castration and days on feed on feed cost of gain of Holstein bulls and steers fed a common diet for different days

	Steers				Bulls					*P*-Value[2]				
Item	308[1]	343	378	413	308	343	378	413	SEM	CAST	L	Q	L int	Q int
Total Feed Cost, $/animal[3]	1295	1396	1622	1724	1358	1641	1738	1886	47.3	<0.01	<0.01	0.33	0.59	0.33
Total BWG, lb/animal	665.0	681.0	779.7	828.7	704.3	760.3	825.7	894.7	23.81	<0.01	<0.01	0.51	0.76	0.77
Trim Yield, lb/animal	460.5	460.1	513.5	532.5	483.5	527.6	530.1	584.8	18.05	<0.01	<0.01	0.56	0.75	0.86
Feed COG, $/lb BWG	1.95	2.06	2.09	2.08	1.93	2.16	2.10	2.10	0.048	0.40	<0.01	0.02	0.90	0.40
Feed Cost, $/lb TY	2.82	3.04	3.16	3.24	2.81	3.11	3.28	3.23	0.097	0.55	<0.01	0.09	0.95	0.48

[1]Average days on feed

[2] CAST = castration status; L = linear response for main effect of days on feed (DOF), Q = quadratic response for main effect of DOF, L int = linear interaction between castration status and linear DOF, Q int = quadratic interaction between castration and quadratic DOF

[3]Prices used for calculation on a DM basis: fish meal = $1933.80/ton after a 5% shrink; field peas = $622.40/ton after a 5% shrink; dry rolled corn = $403.68/ton after a 2% shrink; alfalfa haylage = $290.74/ton after a 15% shrink

Cattle were harvested at JBS in Omaha, NE over a period of 3 days for each harvest event in the order of heavy block, middle block, and light block so that identification of individual carcasses could be preserved through fabrication. Individual HCW was collected at harvest. Dressing percentage (DP) was calculated using the pen average of HCW and final live BW. Following a 24-h chill, 12th-rib fat depth, longissimus muscle (LM) area, and marbling score were collected. Kidney-pelvic-heart (KPH) fat was assumed to be 1.5% for all animals in all harvest events, and yield grade was calculated. Preliminary yield grade was used to calculate 12th-rib fat thickness. At fabrication, carcasses from each pen were deboned and all meat was treated as boneless trim, collected in combo bins, and weighed to obtain trim yield. Samples of each combo bin of trim were collected by JBS employees and were used to measure fat and lean composition of the trim, which was also used to calculate yields of fat trim and lean trim.

A feed cost of gain analysis was conducted using the prices of organic feed applied to the DMI to calculate total feed costs for each treatment group. Prices used for calculation on a DM basis were as follows: fish meal = $1933.80/ton after a 5% shrink; field peas = $622.40/ton after a 5% shrink; dry rolled corn = $403.68/ton after a 2% shrink; alfalfa haylage = $290.74/ton after a 15% shrink. Feed costs were expressed on a per animal basis. Total live BW gain (BWG) and trim yield in lb/animal were used to calculate feed cost of gain per lb of BWG or feed cost per lb trim yield. Data such as yardage, veterinary costs, and death loss were not included in this analysis.

Data were analyzed as a randomized complete block design using the GLIMMIX procedure of SAS (9.3, SAS Institute Inc., Cary, NC) and means were estimated using the LSMEANS option of SAS. Pen was the experimental unit and block was considered a fixed effect. Linear and quadratic interactions between DOF and castration and linear, quadratic, and cubic effect of DOF were examined using contrasts.

Results

Bulls had heavier initial BW and 6.0% greater final BW than steers ($P < 0.01$). Compared to steers, bulls had 7.5% greater ADG ($P < 0.01$) and greater DMI in lb/d ($P < 0.01$). However, no difference was observed in DMI between bulls and steers when expressed as a percent of average BW ($P = 0.44$). No difference in F:G was observed for castration status ($P = 0.31$).

Bulls had 5.9% greater HCW than steers ($P = 0.01$); however, dressing percentage was not different between bulls and steers ($P = 0.96$). Bulls had 21.1% greater LM area and 8.1% greater trim yield in lb/animal than steers ($P < 0.01$). Bulls also had greater trim yield as a percent of HCW than steers ($P \leq 0.05$). Steers had greater 12th-rib fat depth than bulls ($P < 0.01$). Trim lean in lb/animal was 14.4% greater for bulls than for steers ($P < 0.01$). A tendency for an interaction between castration status and DOF was observed for trim yield as a percent of HCW ($P = 0.09$) as bulls tended to increase in trim yield as a percent of HCW over time while steers did not. A tendency for an interaction was also observed for trim lean in lb/animal ($P = 0.10$) as bulls tended to increase in trim lean at a greater rate than steers as DOF increased. There was a linear interaction between castration status and DOF for marbling score, with both steers and bulls increasing in marbling score over time but steers increasing at a greater rate ($P < 0.01$). Linear interactions between castration status and DOF were observed for trim lean percentage, trim fat percentage, and trim fat in lb/animal ($P \leq 0.02$) because steers increased in fat content of trim yield as DOF increased, while bulls appeared to maintain or decrease in trim fat content while trim lean percentage increased as DOF increased. Bulls had lower YG than steers ($P < 0.01$), which was driven by bulls having greater LM area and HCW and decreased 12th-rib fat depth compared to steers.

Final BW and DMI in lb/d increased linearly for both bulls and steers across days on feed ($P \leq 0.05$). A linear increase in F:G and a linear decrease in DMI as a percent of average BW was observed with increasing DOF ($P < 0.01$). A tendency for a linear decrease in ADG was observed as DOF increased ($P = 0.09$).

Carcass weights increased linearly as DOF increased ($P < 0.01$), but no change in DP ($P = 0.37$) or YG ($P = 0.11$) was observed over time. Longissimus muscle area increased as DOF increased ($P = 0.01$). Trim yield as a percent of HCW did not change as DOF increased ($P = 0.61$); however, trim yield in lb/animal increased as DOF increased ($P < 0.01$). No change in 12th-rib fat depth was observed over DOF ($P = 0.24$). Lean trim in lb/animal increased as DOF increased ($P < 0.05$). The interaction of DOF and castration observed for fat content of the trim was likely influenced by the increase in marbling scores in steers and the increase in LM area observed in bulls as DOF increased.

Total feed cost increased as DOF increased, and bulls had higher total feed costs than steers ($P < 0.01$; Table 3). No difference due to castration status was observed for cost of BWG or feed cost per lb trim yield ($P \geq 0.40$). Feed cost of BWG increased in both a linear and quadratic fashion as DOF increased ($P \leq 0.02$). Feed cost of trim yield increased linearly as DOF increased ($P < 0.01$). A tendency for a quadratic increase in cost of trim yield was also observed ($P = 0.09$). This indicates that feed cost of trim yield increases as DOF increases, while the feed cost of BWG increases at a decreasing rate as DOF increases. No linear or quadratic interactions between castration status and DOF were observed for any variable examined in the cost of gain analysis ($P \geq 0.33$).

Conclusion

Bulls had greater live BW, HCW, and trim yield than steers when fed the same number of days. Steers showed greater linear increase in marbling scores and proportion of trim fat as DOF increased compared to bulls. Bulls had leaner carcass composition over time. Increasing DOF linearly increased live BW, HCW, and trim yield. Feeding bulls in an organic production system may result in an increase in saleable product but did not impact feed cost of gain. However, meat quality is significantly influenced. Feeding bulls may increase profitability in a ground beef production system that is not penalized for low quality beef.

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Effect of Increasing Corn Silage Inclusion in Finishing Diets with or without Tylosin on Performance and Liver Abscesses

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Summary with Implications

A finishing study was conducted to assess the impact of increasing silage inclusion in finishing diets to reduce the prevalence of liver abscesses in beef cattle. Cattle were fed two inclusions of corn silage (15 or 45% of diet dry matter), with or without tylosin for control of liver abscesses. Cattle fed 15% corn silage had a 2% improvement in feed efficiency when tylosin was added to the diet. However, in cattle fed 45% corn silage, no improvements in feed efficiency were observed when tylosin was added to the diet. Cattle fed 15% corn silage without tylosin, had the greatest prevalence of liver abscesses (34.5%) compared to other treatments, and abscess prevalence was decreased to 19% if tylosin was fed with 15% corn silage. Feeding 45% silage was effective at lowering liver abscess prevalence which was 12.4%, regardless of whether tylosin was fed. Feeding corn silage at 45% of diet dry matter was as effective as feeding tylosin at controlling abscess rates. Feeding corn silage at greater inclusions decreased average daily gain but increased final body weight when fed to an equal fatness (28 days longer). Feeding elevated concentrations of corn silage in diets containing distillers grains may be a viable method to control liver abscesses without antibiotic use, but has performance implications.

Introduction

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 of liver abscesses, but these alternatives must be efficacious. Feeding high concentrations of corn silage can be economical, efficient, and potentially decrease the risk of liver abscesses in cattle. Increasing corn silage by replacing corn grain increased feed conversion (F:G) and reduced average daily gain (ADG) in cattle but can still be economical. The main objective of this project was to determine if an increase in corn silage in the diet would decrease the prevalence of liver abscesses without the inclusion of tylosin.

Table 1. Composition (% of diet DM) of dietary treatments fed to calf-fed steers with or without tylosin

	Treatment[1]			
Ingredient	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
Wet distillers grains	20	20	20	20
Supplement[2]	4	4	4	4

[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 included 0.5% urea and Rumensin (Elanco Animal Health) at 30 g / ton DM. If tylosin was included, it was formulated to supply Tylan (Elanco Animal Health) at 8.8 g / ton DM. FD & C Blue Dye: water-soluble artificial blue dye allowed by the FDA for use in foods; was used to identify correct supplement delivery. 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. 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.

Procedure

Corn silage was harvested at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, Nebraska, between August 27 and 31, and on September 10, 2018. Corn silage harvest was initiated when the field was approximately ¾ milkline and 37% DM. Silages were stored in sealed silage bags and opened after 21 days.

Crossbred calf-fed steers (n = 640; initial body weight [BW] 586 ± 30 lbs) were sorted into 2 BW blocks and assigned randomly to one of 32 pens (20 steers/pen). The light block included 2 replications, and the heavy block included 6 replications per treatment. Cattle were started at two time points starting on November 20 for block 1 and November 30 for block 2. All steers were weighed on 2 consecutive days after limit-feeding a common diet of 50% alfalfa hay and 50% Sweet Bran at 2% of BW for 5 days.

Treatments were arranged as a 2×2 factorial, that consisted of two inclusions of corn silage (15 or 45%), with (TCS15, TCS45) or without tylosin (CS15, CS45; Table 1). All steers were fed monensin (Rumensin, Elanco Animal Health) at 30 g/ton of DM and tylosin (Tylan; Elanco Animal Health) was included at 8.8 g/ton of DM for the two treatments including tylosin. Feed was delivered once daily.

Steers were implanted with a Revalor-IS (Merck Animal Health) on d 1 and then re-implanted with a Revalor-200 (Merck Animal Health) on day 75 and 85 for blocks 1 and 2, respectively. Cattle fed 15% corn silage were shipped on May 28th after 185 days on feed. To achieve similar fatness, cattle fed 45% corn silage were shipped 4 weeks later, on June 25th after 213 days on feed.

On the day of harvest, hot carcass weight (HCW) was recorded, and carcass-adjusted final BW was used to determine average daily gain (ADG) and feed conversion (F:G). On the day of harvest, liver

Table 2. Simple effects for carcass adjusted performance of cattle fed 15 or 45% corn silage with or without tylosin

	Treatment[1]							
	- Tylosin		+ Tylosin			*P*-value		
	CS15	CS45	TCS15	TCS45	SEM	Tylosin × Silage	Tylosin	Silage
Days on Feed	185	213	185	213	-	-	-	-
Initial BW, lbs	646	646	645	646	10.7	0.97	0.94	0.97
Live final BW, lbs	1282	1336	1294	1339	14.6	0.77	0.60	< 0.01
Carcass Adjusted Performance								
Final BW, lbs	1281	1336	1296	1328	16.1	0.51	0.82	0.01
DMI, lbs / d	21.7	23.1	21.7	23.1	0.25	0.94	0.86	< 0.01
ADG	3.43	3.24	3.52	3.21	0.046	0.21	0.55	< 0.01
G:F	0.158[b]	0.140[c]	0.162[a]	0.139[c]	0.0015	0.10	0.27	< 0.01
F:G	6.34	7.15	6.16	7.21	-	-	-	-
Carcass Characteristics[3]								
HCW, lbs	807	841	816	837	10.2	0.53	0.84	0.01
LM area, in^2	13.9	13.8	13.9	13.6	0.14	0.53	0.53	0.18
12th rib fat, in	0.48	0.49	0.46	0.49	0.014	0.50	0.69	0.10
Marbling[4]	456	446	440	445	7.14	0.33	0.25	0.69
Calculated Yield Grade[5]	2.82	3.01	2.83	3.07	0.05	0.60	0.54	< 0.01
Quality Grade	3.07	3.13	3.2	3.14	0.06	0.30	0.23	0.97
Dressing, %	63.2	63.2	63.3	62.7	0.14	0.20	0.33	0.15
Liver abscesses[6]	34.5[a]	12.0[b]	19.2[b]	12.7[b]	5.55	0.05	0.09	< 0.01

[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 as 2.5 + (2.5 x 12th rib fat) + (0.2 x 2.0 [KPH]) + (0.0038 x HCW) – (0.32 x LM area).

[6] Calculated as a percent of total steers; dead steers removed

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. Carcass characteristics, recorded after a 48-h chill, included marbling score, 12th rib fat thickness, and LM area.

Data were analyzed using the PROC MIXED procedures of SAS 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. Post-trial, hot carcass weight was analyzed within liver abscess severity category. Liver abscess category, treatment, and the interaction between liver abscess category and treatment were used as fixed effects. An economic analysis was reported in *2021 Nebraska Beef Cattle Report*, pp. 69–71.

Results

By design, all cattle were fed to a similar 12th rib fat thickness ($P = 0.10$) to ensure equal degree of finish when comparing performance and carcass characteristics. Cattle fed 45% corn silage were fed for 213 days and 15% corn silage were fed for 185 days (Table 2).

There was an interaction for feed conversion ($P = 0.10$). Cattle fed 15CS with tylosin (T15CS) had the lowest F:G, 15% corn silage without tylosin (15CS) was intermediate, and both 45% corn silage with and without tylosin (45CS and T45CS) had the poorest feed conversion. Cattle fed 15CS had a 3% decrease in F:G when tylosin was added to the diet. However, in cattle fed 45CS, no improvements in F:G were observed when tylosin was added to the diet.

There were no interactions for live final BW, carcass-adjusted final BW, HCW, dry matter intake (DMI) or average daily gain (ADG; $P \geq 0.21$), so main effects of silage inclusion or tylosin inclusion will be discussed. Cattle fed 45% corn silage had greater ($P \leq 0.01$) live final BW, carcass-

Table 3. Hot carcass distributions relationship with categorical liver abscess score

	Liver score					
Item	0	A-	A	A+	SEM	*P*-value[1]
Cattle, n	501	50	26	49	-	-
Hot Carcass Weight						
Minimum	610	678	693	601	-	-
Maximum	1054	935	924	924	-	-
Standard Deviation	59.6	59.0	51.5	75.0	-	-
Average	829	814	825	785	32.3	< 0.01

[1]Treatment × Liver abscess score: $P = 0.29$

adjusted final body weight, and HCW compared to cattle fed 15% corn silage due to the greater days fed to equalize fatness. Cattle fed 45% corn silage had greater DMI but lower ADG compared to cattle fed 15% corn silage ($P \leq 0.01$). There was no effect of silage inclusion on longissimus muscle area (LM area), marbling, dressing percentage, or quality grade. Calculated yield grade was greater for cattle fed 45% corn silage ($P < 0.01$). Additionally, there was a significant shift in USDA YG distributions between 15 or 45% silage treatment with cattle fed 45% silage being slightly fatter ($P = 0.10$) with greater USDA YG ($P < 0.01$). There was no effect of tylosin for live or carcass-adjusted final BW, or HCW. Additionally, tylosin did not affect DMI or ADG ($P \geq 0.55$).

Overall, in this study liver abscess prevalence ranged from 12.0 to 34.5%. There was an interaction for liver abscesses, where cattle fed CS15 (no tylosin) had the greatest prevalence of liver abscesses (34.5%) compared to all other treatments ($P = 0.05$; Table 2). Cattle fed 15CS benefited from the addition of tylosin in the diet by reducing the prevalence of liver abscesses from 34.5% to 19.2% (44.3% reduction). However, no differences in prevalence were observed when cattle were fed 45% corn silage with tylosin (12.7%) or without tylosin (12.0%).

Additionally, there was a tendency for an interaction ($P = 0.11$) between corn silage and tylosin inclusion for the distribution of abscess severity (data not shown). In addition to having the greatest prevalence of liver abscesses, cattle fed 15CS (no tylosin) also had the greatest number of severe abscesses, with 27.8% A or A+ liver abscesses. Severity was lessened (fewer A+) when cattle were fed T15CS (with tylosin). Cattle fed 45CS and T45CS had comparable distributions in severe liver abscesses. 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 liver abscesses further.

An exploratory analysis was conducted to determine hot carcass distributions relationship with categorical liver abscess score (Table 3). Hot carcass weight was significantly reduced when cattle were scored with A+ livers (785 lbs), compared to other severity categories (A-, 814 lbs; A, 825 lbs) and cattle with no abscesses (829 lbs). Cattle with A+ abscesses had the greatest standard deviation with the lowest minimum and maximum carcass weights. The distributions of hot carcass weight are similar for steers with livers that were scored 0, A-, or A. However, when steers had A+ livers the distribution of hot carcass weights for those animals shifted to the left, leading to an overall lower average, but an increase in standard deviation across the mean. Additionally, 50% of steers with an A+ liver score had a hot carcass weight of 800 lbs or lighter. However, steers with scores of 0, A, or A- were heavier with only an average of 15% of cattle with hot carcass weights of 800 lbs or lighter. Only severe abscesses (A+) reduced hot carcass weight in this study. Because the trial was not able to measure live final body weight 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.

Conclusion

Cattle fed 45% corn silage had poorer gain and conversions but greater final body weights when finished to a common fat thickness compared with cattle fed 15% corn silage. Feeding tylosin in diets containing 85% concentrate led to a decrease in prevalence of liver abscesses. However, feeding corn silage at 45% also decreased the prevalence of liver abscesses with or without the inclusion of tylosin.

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Economic Analysis of Increased Corn Silage Inclusion in Beef Finishing Cattle

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Summary with Implications

An economic analysis was conducted to assess the feasibility of feeding greater inclusions of corn silage in finishing diets. Cattle were fed two inclusions of corn silage (15 and 45% of diet dry matter) with or without tylosin. Cattle fed 15% corn silage with tylosin had the best feed conversion, 15 % corn silage without tylosin was intermediate, and both 45% corn silage with and without tylosin had the poorest feed conversion. Feeding corn silage at greater inclusions decreased ADG but increased final body weight when fed to an equal fatness (28 days longer). However, feeding corn silage at 45% was more economical compared to feeding 15% corn silage, especially at higher corn prices, provided shrink is well managed (less than 15%). Feeding elevated concentrations of corn silage may have an economic advantage while also offering the addition of liver abscess control in finishing diets without tylosin.

Introduction

Approximately 45% of feedyard cattle are finished in Nebraska, Iowa, and Kansas. Increasing silage inclusion in finishing diets decreased the risk of liver abscesses in cattle. Increasing corn silage by replacing corn grain reduces feed conversion and lowers average daily gain (ADG) of cattle but may still be economical (*2013 Nebraska Beef Cattle Report*, pp. 76–77; *2013 Nebraska Beef Cattle Report*, pp. 74–75; *2019 Nebraska Beef Cattle Report*, pp. 69–71; *2020 Nebraska Beef Cattle Report*, pp. 71–74). Traditional sources of roughage, like alfalfa and brome, can pose problems for feedyards due to bulk size and increased cost. However, 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. Historically when corn was relatively expensive, corn silage was used to partially replace corn as an energy source in finishing diets. 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. The objective was to determine if feeding more corn silage in finishing cattle would be equally or more profitable with and without the use of antibiotics.

Procedure

Performance data were used from *2021 Nebraska Beef Cattle Report*, pp. 66–68. Briefly, 640 steers were fed in a 2 × 2 factorial, that consisted of two inclusions of corn silage (15 or 45%), with or without tylosin. Corn silage was harvested at ENREC between August 27 and 31, and on September 10, 2018. Corn silage harvest was initiated when the field was approximately ¾ milkline and 37% DM.

Dry corn price was calculated using $3.67 / bu, while corn silage was priced at $43.99 per ton as-is ($110 ton DM, 37% DM; Iowa State University corn silage pricing application). Costs and inputs used to calculate the price of corn silage are briefly described in Table 1. The following inputs for expected production were 60 acres and 28 tons of silage (37% DM) per acre (based on expected corn yield with 6% yield drag). The opportunity cost of harvesting and selling corn stover ($28.84 / ton) as well as the cost to replace phosphate ($0.34 / lbs phosphate fertilizer) and potash ($0.25 / lbs potash fertilizer) after stalk removal was subtracted. Total replacement is estimated at 3.5 lbs/ton phosphate and 9 lbs / ton potash. Harvest and storage costs included $38.22 / acre for harvesting using a forage harvester and $0.10 / ton for hauling and storing, accounting for 15% shrink loss. A credit was given for manure value. Manure credit was assessed as spreading 1 out of every 4 years in a rotation to provide enough phosphorus for 4 years. The value of manure was calculated using The Beef Feed Nutrient Management Planning Economics (BFNMP$) tool using 45% silage-based diet with 20% WDGS, adding up to a total value of $2.83 / ton of silage intake. Cattle interest costs were set at 7.5% of the initial purchase price over the feeding period (Days on feed / 365) minus $200 deposit. The cost of WDGS was set at 90% the price of corn (DM basis) including 5% shrink. Supplement, including monensin, was $300 / ton (DM basis) with 1% shrink applied. 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. A 5-year average (May 2014—May 2019) for feeder price in Nebraska ($1.3952 / CWT; Livestock Marketing Information Center) was used to target a net return of $0 / steer for cattle on the 15% silage treatment. Revenue was calculated as the difference in gross inputs and revenues where values represented profit in dollars per steer ($ / steer) and were calculated using final body weights with a 63% common dressing percent.

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). Corn silage prices changed with the price of corn. Corn silage (at 37% DM) price compared to $3.00, $4.00, and $5.00/ bu corn was $38.84 (per tons as is, 37% DM), $42.66, $46.57, respectively. Revenue was calculated using a single 5-year average for live fed price for Nebraska ($1.2500 / cwt). However, feeder price decreased with increasing corn price

Table 1. Expected production, inputs, and opportunity costs used for calculating the cost of harvesting and feeding corn silage

Item	Production / Costs
Expected Production	
Expected Yield (grain DM = 50% of total)	> 150 bu (50% grain DM)
Estimated % moisture for corn silage when harvested	63%
Actual silage yield, tons / acre, 6% yield drag	28 tons
Bushels of corn per ton of silage (bu / ton silage), 6% yield drag	7.82 tons
Corn stover produced, ton	4.53 tons
Phosphate fertilizer to replace stalks removed (lbs / ton harvested)	0.32 lbs / ton
Potash fertilizer to replace stalks removed (lbs / ton harvested)	0.22 lbs / ton
Harvesting Costs	
Corn price, $ / bushel, Sept. Price	$3.67
Grass hay, $ / ton	$100
Cost of phosphate fertilizer ($ / lbs; from above)	$0.34
Cost of potash fertilizer ($ / lbs; from above)	$0.25
Grain and stover harvesting, $ / acre (includes Combining)	$72.36
Hauling and storing, $ / ton	$1.10
Value based on opportunity cost to seller ($ / ton silage)	
Lost gross revenue from not harvesting corn grain	$28.84
Lost gross revenue from not harvesting corn stover	$4.05
Fertilizer cost for nutrient removal if harvested as silage	$1.85
Nutrient replacement from silage (added value)	-$2.83
Manure Spread Cost (45% corn silage diet)	$0.90
Drying and storage costs savings for corn grain and stover	$3.77
Equals opportunity cost of selling silage in the field	$28.14
Harvesting and storage costs for silage	$12.89
Shrink of Silage (15% DM shrink)	$4.97
Opportunity cost of selling stored silage	$42.42
Feed value of silage (as-is; 37% DM)	$43.99
Ingredient and Processing Costs	
Corn Silage, calculated from above ($ / ton DM)	$118.89
WDGS ($ / ton DM)	$138.78
DRC ($ / ton DM)	$154.20
DRC processing ($ / ton DM)	$2.17
Supplement ($ / ton DM)	$300
Animal processing ($ / animal)	$20
Tylosin (if included; $ / animal daily)	$0.01
Yardage ($ / animal daily)	$0.50
Initial Purchase Price ($ / CWT)	$1.66
Sale Price ($ / CWT)	$1.20

WDGS= Wet distillers grains plus solubles; DRC = Dry rolled corn; CWT = hundred weight (100 lbs)

to achieve breakeven ($0 net return) for the 15% corn silage treatment.

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.

Results

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. Cattle fed 45 CS were fed for 213 days and 15 CS were fed for 185 days (Table 2). Performance results were reported in *2021 Nebraska Beef Cattle Report*, pp. 66–68. Briefly, there was an interaction for feed efficiency ($P = 0.10$). Cattle fed 15% CS with tylosin (15TCS) had the lowest F:G, 15 % corn silage without tylosin (15CS) was intermediate, and both 45% corn silage with and without tylosin (45CS and 45TCS) had the poorest feed conversion. Cattle fed 15% corn silage had a 2% decrease in F:G when tylosin was added to the diet. However, in cattle fed 45%, no improvements in F:G were observed when tylosin was added to the diet.

There was a tendency for an interaction ($P = 0.14$; Table 2) 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 (with no tylosin), the reduced feed costs and increased body weights 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

Table 2. Simple effects for carcass adjusted performance of cattle fed 15 or 45% corn silage with or without tylosin

	Treatment[1]							
	- Tylosin		+ Tylosin			*P*-value		
	CS15	CS45	TCS15	TCS45	SEM	Tylosin × Silage	Tylosin	Silage
Days on Feed	185	213	185	213	-	-	-	-
Initial BW, lbs	646	646	645	646	10.7	0.97	0.94	0.97
Live final BW, lbs	1282	1336	1294	1339	14.6	0.77	0.60	< 0.01
Carcass Adjusted Performance								
Final BW, lbs	1281	1336	1296	1328	16.1	0.51	0.82	0.01
DMI, lbs / d	21.7	23.1	21.7	23.1	0.25	0.94	0.86	< 0.01
ADG	3.43	3.24	3.52	3.21	0.046	0.21	0.55	< 0.01
F:G	6.34[b]	7.15[c]	6.16[a]	7.21	-	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, lbs	807	841	816	837	10.2	0.53	0.84	0.01
12th rib fat, in	0.48	0.49	0.46	0.49	0.014	0.50	0.69	0.10

[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.

Table 3. Estimated returns ($ / steer) at varying corn prices for three inclusions of corn silage fed to feedlot cattle[1]

		Returns by Treatment[2]	
Dry Corn Price[3], $ / bu	Feeder Calf Price[4], $ / cwt	CS15, $ / animal	CS45 $ / animal
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 ($1.2500 / cwt).

[2] CS = corn silage.

[3] Corn silage prices floated with the price of corn utilizing a September corn price comparison ($-0.20 / bu) compared to $3, $4, and $5 dry corn. The corn silage prices were $38.84 (as-is, 37% DM), $42.66, $46.57, respectively.

[4]Initial purchase price was set to break even for 15% corn silage.

economical in times of high corn prices. Differences in returns ($ / steer), based on corn price, were evaluated at the varying inclusions of corn silage (Table 2). 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 (Table 3).

Conclusion

These data suggest, as corn becomes more expensive, it becomes more economical to feed corn silage at greater inclusions. 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. If more silage is fed (up to 45%), then cattle need to be fed longer to get to a similar fat endpoint, so grade is not hindered. By feeding cattle 45% corn silage for 28 days longer, there was more sellable carcass weight (and live weight). Despite increased yardage and feed inputs, the diet cost was sufficiently cheaper, and the cattle were heavier (+27 lb) which increased profitability by $10.50 per animal. This a system-based approach to integrate, utilize, and optimize corn acres while having the greatest economic impact on cattle feeding.

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Fate of Generic *Escherichia coli* in Beef Steaks during Sous Vide Cooking at Different Holding Time and Temperature Combinations

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Summary with Implications

Sous vide cookery utilizes water baths held at precise temperatures to cook food and has increased in popularity in domestic and food service settings due to ease of use and consistent final cooking temperature of food. Some sous vide manufacturers' cooking websites suggest cooking intact and non-intact beef products to internal temperatures as low as 115° F. To address the safety concerns of cooking non-intact beef products to temperatures below USDA-FSIS guidance temperatures, steaks were internally inoculated with a strain of generic E. coli *and sous vide cooked to internal temperatures of 115, 125, 130, and 145° F and held for various times. A 5 log_{10} reduction of generic* E. coli *was achieved after sufficient holding times for all temperatures except 115° F, which only achieved 1.07 log_{10} reduction after 420 minutes of holding. These worst-case scenario results highlight the importance of using safe time and temperature combinations when sous vide cooking beef and warrant further investigation using pathogenic* E. coli.

Introduction

Sous vide cooking has grown in popularity as cooking units have become more affordable and easier to use. This method of cooking by submerging a vacuum sealed product in a hot water bath held at a precise temperature allows for an exact degree of doneness throughout the product. However, some cooking guidelines distributed by sous vide manufacturers for cooking of beef create the potential for foodborne illness due to recommended cooking temperatures as low as 115° F. The United States Department of Agriculture, Food Safety and Inspection Service (USDA-FSIS) Appendix A guidance for the control of *Salmonella* is commonly referenced for the control of pathogenic *E. coli* in cooked beef products since *Salmonella* is more heat resistant than pathogenic *E. coli*. The shortest time and lowest temperature combination included in Appendix A requires achieving 130° F and holding for 86 minutes. The objective of this experiment was to validate a 5 log_{10} thermal reduction of generic *E. coli* in sous vide cooked beef steaks at various time and temperature combinations, including those outside USDA recommendations.

Table 1. Concentration of *E. coli* (log_{10} cfu/g) during sous vide cooking.

Holding time (min)	log_{10} cfu/g	Total Reduction
115° F holding temperature		
Raw steak	7.41[a]	n/a
150	7.37[a]	0.04
420	6.33[b]	1.07
125° F holding temperature		
Raw steak	7.02[a]	n/a
150.0	3.88[b]	3.14
193.5	2.21[c]	4.81
258.0	1.22[d]	5.80
322.5	0.39[e]	6.63
130° F holding temperature		
Raw steak	7.13[a]	n/a
64.5	0.51[b]	6.62
86.0	0.47[b]	6.66
107.5	0.73[b]	6.12
145° F holding temperature		
Raw steak	7.25[a]	n/a
2.25	0.42[b]	6.83
3.00	0.42[b]	6.83
3.75	0.58[b]	6.67

[a-e]Concentrations with different superscripts within each temperature treatment were different ($P < 0.05$).

Procedure

The experiment was conducted in three independent replications. Beef *semitendinosus* muscles, eye of round, were cut into 1" slices, vacuum packaged, and frozen until use. For each replication, steaks were thawed (48 hours at 39° F) and exposed to UV light for 15 minutes on each side to reduce natural microflora. Steaks were submerged in liquid inoculum (2 liters of *E. coli* ATCC 25922 overnight culture, approx. 8 log_{10} colony forming units (cfu)/g) and internally inoculated with a pin pad inserted five times into each side of each steak to achieve a 7 log_{10} cfu/g concentration. After inoculation, steaks were air-dried (30 min, 73° F), individually vacuumed sealed, and cooked in sous vide water baths. For cooked steaks, holding time started once the steak reached the target internal temperature. Duplicate steak samples were taken from raw, inoculated steaks and from steaks subjected to the following hold time/

temperature combinations: 150 min/115° F, 420 min/ 115° F, 150 min/125° F, 193.5 min/125° F, 258 min/125° F, 322.5 min/125° F, 64.5 min/130° F, 86 min/130° F, 107.5 min/130° F; 2.25 min/145° F, 3 min/145° F, and 3.75 min/145° F. The median sampling times for 130° F and 145° F were taken directly from the Appendix A 5 $\log_{10}$ reduction table, and the other times were +/- 25% of the intermediate time. The 258 min sampling time for 125° F was extrapolated from the table. The 115° F sampling times represented potential worst-case scenarios and sous vide manufacturer's cooking guidance. Core samples (25 g) were homogenized, serially diluted, and plated onto Charm EC Peel plates for rapid detection of *E. coli* concentrations. *E. coli* colonies were counted after incubation (24 hours at 95° F) according to manufacturer guidelines and reported as $\log_{10}$ cfu/g. Reductions were determined by subtracting concentrations at given sampling times from the raw sample. Data were analyzed using PROC GLM contrasts in SAS 9.4.

Results

The minimum holding time (time at target internal temperature) measured for a 5 $\log_{10}$ cfu/g reduction for 125, 130, and 145° F was 258 , 64.5 , and 2.25 minutes, respectively ($P < 0.01$; Table 1). These data confirm the utility of Appendix A time, temperature tables for a 5 $\log_{10}$ cfu/g reduction of generic *E. coli* at 130 and 145° F and suggest the possibility for safely sous vide cooking steaks at 125° F. Alternatively, 115° F cooking was insufficient for reducing the target concentrations of *E. coli*, with a final reduction of only 1.07 $\log_{10}$ cfu/g ($P < 0.01$) after 420 minutes. Although a pathogenic strain of *E. coli* was not used in this study, the insufficient reduction of generic *E. coli* at 115° F highlights the potential risk of sous vide cooking beef at low temperatures. Further experimentation is needed to determine the fate of pathogenic *E. coli* during sous vide cooking of steaks using time and temperature combinations at and below recommended by USDA-FSIS.

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Proteomic Analysis of Oxidized Proteins in Beef

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Summary with Implications

To evaluate the effects of diet and quality grade on tenderness and oxidative damage to proteins, strip loins from USDA Upper 2/3rd Choice and Select- grade carcasses were obtained. Steers were fed either a diet containing dry rolled corn, steam flaked corn, dry rolled corn with 30% dried distillers grains with solubles, or steam flaked corn with 30% dried distillers grain with solubles. Results suggest that steaks from steers fed dry rolled corn are more objectively tender than steam flaked corn; in addition, steaks grading USDA Upper 2/3rd Choice steaks were more tender when compared to USDA Select quality grade. In contrast to previous research, no tenderness differences were detected between steaks from steers with or without dried distillers with solubles. Proteomic analysis revealed increased oxidative damage of myofibrillar proteins. Steaks graded as USDA Upper 2/3rd Choice steaks were determined to generally have increased oxidative damage to glycolytic, structural, and heat shock proteins, compared to USDA Select quality grade. While samples from steers fed dry rolled corn were more tender and had increased myofibrillar oxidative damage from steers fed DRC with distillers grains, steam flaked corn- related treatment displayed the inverse response. Overall, results support the relationship between marbling and tenderness, and suggest oxidative stress may be a factor involved in this difference.

Introduction

Recent proteomic research has implicated oxidative stress as a factor that damages myofibrillar antioxidant enzymes, structural, and heat shock proteins. Oxidative stress occurs as a result of increased reactive oxygen species that overwhelms antioxidant defenses in the body, causing cellular damage. While oxidative stress seems to impact tenderness in beef, research in human nutrition has determined high-fat diets can induce oxidative stress. Therefore, high-fat diets like distillers grains may induce oxidative stress in the cattle. It is commonly recognized that feeding high-fat diets such as those containing distillers grains promotes increased rate of marbling deposition. Research has long recognized the evident relationship between marbling and tenderness. Perhaps oxidative damage to proteins occurs in highly marbled beef and thereby potentially enhances tenderness. Therefore, this study was conducted to evaluate the effects of oxidative damage to myofibrillar proteins on beef tenderness, as influenced by diet and marbling.

Table 1. Warner Bratzler Shear Force of strip loin steaks (*L. lumborum*) from steers fed either with dry rolled corn with dried distillers grains with solubles, dry rolled corn without dried distillers grains with solubles, steam flaked corn with dried distillers grains with solubles, or steam flaked corn without dried distillers grains with solubles at USDA Upper 2/3rd Choice or Select quality grade (n=36).

Category					
Grain	DDGS	Quality Grade	WBSF (kgf)	*SEM*	P-value
DRC			3.46[b]	0.2	0.02
SFC			4.04[a]		
	DDGS		3.68	0.18	0.43
	No DDGS		3.84		
		Choice	3.39[b]	0.23	<0.01
		Select	4.11[a]		

[a,b] Means in the same column within a category without common superscripts differ ($P < 0.05$).

WBSF: Warner Bratzler shear force.

DRC: Dry rolled corn.

SFC: Steam flaked corn.

DDGS: Dried distillers grains with solubles.

No DDGS: Without dried distillers grains with solubles.

Procedure

A total of 240 steers were randomly block assigned by weight among 24 pens (10 head/pen) and fed for 202 d on diets containing dry rolled corn (DRC), DRC with 30% dried distillers grains with solubles (DDGS), steam flaked corn (SFC), or SFC with 30% DDGS. Thirty-six USDA Upper 2/3rd Choice and Select carcasses (21 Upper 2/3rd Choice and 15 Select) were selected and strip loins were collected. Beef strip loins were aged for 2 d and then fabricated into steaks for objective tenderness and samples were diced, frozen in liquid nitrogen, and blended into a powdered sample for proteomic analysis.

Tenderness

Internal temperature and initial weight of raw steak (1 inch thick) were recorded. Steaks were cooked to a target temperature of 160°F on a belt grill. The cooked steaks were measured and recorded for internal temperature and weight. The steaks were individually bagged and stored overnight at 36°F for WBSF analysis. On the following day, six (0.5-inch diameter) cores were removed using a drill press going parallel to the muscle fibers and were sheared

Table 2. Characteristics of carbonylated protein spots derived from USDA Upper 2/3rd Choice or Select beef from steers fed dry rolled corn with or without distillers grains.

Spot ID	Protein ID	ABV	Protein	Score	PI/Mw experimental	PI/Mw theoretical	Spot ID	Protein ID	ABV	Protein	Score	PI/Mw experimental	PI/Mw theoretical
DRC without DDGS													
Increased oxidative damage in USDA Upper 2/3rd Choice Quality Grade							Increased oxidative damage in USDA Select Quality Grade						
289	P00570	AK1	Adenylate kinase	1873	9.52/ 24,579	8.40/ 21,664							
DRC with DDGS													
Increased oxidative damage USDA Upper 2/3rd Choice Quality Grade							Increased oxidative damage in USDA Select Quality Grade						
110	P19120	HSPA8	Heat shock cognate 71 kDa protein	139	4.82/ 64,857	5.37/ 71,241	293	P02510	CRYAB	Alpha-crystallin B chain	2675	8.05/ 24,026	6.76/ 20,037
	Q27975	HSPA1A	Heat shock 70 kDa protein 1A	100		5.67/ 70,259	133	P19483	ATP5F1A	ATP synthase subunit alpha, mitochondrial	668	9.29/ 59,143	9.21/ 59,720

Comparisons are made across the table.

Table 3. Characteristic of carbonylated protein spots derived from beef from steers fed dry rolled corn with or without distillers grains at the same quality grade.

Spot ID	Protein ID	ABV	Protein	Score	PI/Mw experimental	PI/Mw theoretical	Spot ID	Protein ID	ABV	Protein	Score	PI/Mw experimental	PI/Mw theoretical
DRC–USDA Upper 2/3rd Choice Quality Grade													
Increased oxidative damage without DDGS							Increased oxidative damage with DDGS						
293	P02510	CRYAB	Alpha-crystallin B chain	2675	8.05/ 24,026	6.76/ 20,037	200	Q8MKH6	TNNT1	Troponin T, slow skeletal muscle	903	6.67/ 38,640	5.71/ 31,284
								Q8MKI3	Tnnt3	Troponin T, fast skeletal muscle	280		5.99/ 32,126
								Q3T145	MDH1	Malate dehydrogenase, cytoplasmic	468		6.16/ 36,438
							156	Q3ZC09	ENO3	Beta-enolase	506	6.93/ 52,000	7.60 /47,096
								Q9XSJ4	ENO1	Alpha-enolase	473		6.37 /47,326
							71	P79334	PYGM	Glycogen phosphorylase, muscle form	248	9.05/ 102,222	6.65 / 97,293
DRC–USDA Select Quality Grade													
Increased oxidative damage without DDGS							Increased oxidative damage in DRC with DDGS Select						
360	O97680	TXN	Thioredoxin	358	5.02/ 16,030	4.97/ 11,813	306	Q148F1	CFL2	Cofilin-2	571	6.69/ 22,842	7.66/ 18,737
358	P11116	LGALS1	Galectin-1	802	5.41/ 16,446	5.32/ 14,744	126	P31081	HSPD1	60 kDa heat shock protein, mitochondrial	686	5.28/ 61,048	5.60/ 61,108
	P00426	COX5A	Cytochrome c oxidase subunit 5A	564		6.42/ 16,735	125	O62654	DES	Desmin	3187	5.14/ 61,048	5.21/ 53,532
104	Q08DP0	PGM1	Phosphoglucomutase-1	1362	8.82/ 68,190	6.36/ 61,589							
	Q3ZBD7	GPI	Glucose-6-phosphate isomerase	730		7.33/ 62,855							

Comparisons are made across the table.

using a texture analyzer using a Warner-Bratzler shear blade. The WBSF values were averaged from each steak for statistical purposes.

Proteomics

About 50 mg of powdered beef samples were utilized to extract, separate, and identify proteins for proteomic analysis. Sample comparisons include evaluating differences due to dietary treatment of DRC with or without DDGS that were Choice or Select quality grade or SFC with or without DDGS that were Choice or Select quality grade.

Statistical analysis

The processing method of corn, addition or absence of DDGS, and quality grade served as the main plot factors. For proteomic analysis, if the protein oxidative damage score was greater than 31, then the comparison was significant. Tenderness determination was analyzed as a randomized complete block design in a 2×2×2 factorial. Data were analyzed using PROC GLIMMIX program of SAS with LSMEANS statement. Specific to the proteomic assay, if the protein score exceeded 31, the difference of protein oxidation, to treatment comparison, was significant. Statistical significance was determined at $P< 0.05$.

Results

No differences ($P= 0.43$) in tenderness were observed to be associated with the addition or absence of DDGS in the diet (Table 1). In previous research, a tenderness advantage has been reported for steaks from cattle fed DDGS, especially early postmortem. Steaks from steers fed DRC had significantly lower WBSF than steaks from steers fed SFC *(*$P< 0.05$*)* indicating that steers fed DRC were more tender than steers fed SFC. Also, there was a difference in tenderness between USDA Upper 2/3rd Choice and Select strip loins ($P< 0.05$), with USDA Upper 2/3rd Choice having lower WBSF. The lower the WBSF value, the more tender the sample. These results suggest that while the addition of DDGS may not improve tenderness, the substitution of DRC for SFC can improve tenderness along with improving USDA quality grade through fat deposition in the marbling adipocytes.

Protein oxidation in dry-rolled corn treatment

When comparing the different quality grades from steers fed DRC without DDGS diet (Table 2), there was an increase of oxidative damage in adenylate kinase for USDA Upper 2/3rd Choice, compared to Select. While adenylate kinase is a nucleotide myofibrillar protein involved in maintaining muscular homeostasis, it had increased oxidative damage of myofibrillar proteins in tender beef in previous research. In beef from steers fed DRC with DDGS, some heat shock proteins exhibited oxidative damage for USDA Upper 2/3rd Choice, compared to Select. Conversely, USDA Select carcasses had greater oxidative damage to α crystallin β chain and ATP synthase proteins. Given the tenderness advantage for the USDA Upper 2/3rd Choice carcasses, these results suggest that oxidative damage to certain proteins can be associated with increased tenderness.

For the USDA Upper 2/3rd Choice carcasses from steers fed a DRC diet, the addition of DDGS was associated with a wide array of oxidative damage of proteins (Table 3), including slow-twitch skeletal muscle and fast-twitch skeletal muscle fiber troponin T, and β-enolase, and malate dehydrogenase. While troponin T degradation has long been recognized as an indicator of improved tenderness, degradation of β-enolase is a protein only recently been reported to indicate improved tenderness. Intact malate dehydrogenase, alternatively, has been positively related to improved tenderness. For the USDA Select beef from steers fed DRC diet treatment, the addition of DDGS was associated with increased oxidative damage to the structural protein desmin and heat shock protein 60kDa. As heat shock proteins help stabilize cells and have been related to increased toughness in beef, increased oxidative damage of heat shock proteins are related to improved tenderness. Similarly, damage to desmin would support improved tenderness. For USDA Select beef from cattle fed DRC without DDGS, oxidative damage was associated with apoptotic proteins galectin and cytochrome-c oxidase. Apoptotic proteins have been hypothesized to improve tenderness, so increased oxidative damage of those proteins may negatively impact tenderness.

Protein oxidation in the steam-flaked corn treatment

When comparing quality grades beef from steers fed SFC without DDGS diet (Table 4), there was an increase of oxidative damage in a heat shock protein in USDA Select beef carcasses. Increased oxidation of heat shock proteins is often associated with more tender meat; however, the tenderness data do not support that USDA Select beef was more tender than USDA Upper 2/3rd Choice beef carcasses.

When including DDGS in the SFC diet (Table 4), USDA Upper 2/3rd Choice beef carcasses had considerably more proteins that were oxidized than USDA Select beef, including oxidation of structural proteins (the actinins) and proteins associated with glycolysis. The glycolytic enzymes are not only valuable to producing energy in low oxygen conditions but during slaughter when the lack of oxygen shunts energy production to mostly glycolysis and the lactic acid pathway. Damage to such systems could conceivably allow early postmortem release of calcium, stimulating calpain enzymes which accelerate tenderization. Alternatively, there was more sustained oxidative damage in myosin and a few glycolytic proteins in USDA Select beef when compared to USDA Upper 2/3rd Choice beef. The impacts of these changes are unknown.

In contrast to DRC, SFC without DDGS resulted in more proteins sustaining oxidative damage within USDA Upper 2/3rd Choice beef from steers fed SFC containing DDGS (Table 5). The oxidized proteins include myosin, tropomyosin, and cytochrome b-c1 complex. With myosin and tropomyosin being structural proteins, increased oxidative damage may indicate decreased structural integrity at the actomyosin cross-bridge, which may improve tenderness. Damage to cytochrome b-c1 complex can impact ATP production by negatively impacting the electron transport chain. Furthermore, it may impact cytochrome c, a protein that can influence apoptotic processes. Similar to these observations with USDA Upper 2/3rd Choice, the

Table 4. Characteristics of carbonylated protein spots derived from USDA Upper 2/3rd Choice or Select beef from steers fed steam flaked corn with or without distillers grains.

Spot ID	Protein ID	ABV	Protein	Score	PI/Mw experimental	PI/Mw theoretical	Spot ID	Protein ID	ABV	Protein	Score	PI/Mw experimental	PI/Mw theoretical
SFC without DDGS													
Increased oxidative damage in USDA Upper 2/3rd Choice Quality Grade							Increased oxidative damage in Select Quality Grade						
							150	P19120	HSPA8	Heat shock cognate 71 kDa protein	4116	3.45/ 65,684	5.37/ 71,241
SFC with DDGS													
Increased oxidative damage USDA Upper 2/3rd Choice Quality Grade							Increased oxidative damage in Select Quality Grade						
282	P19858	LDHA	L-lactate dehydrogenase A chain	2382	9.33/ 36,495	8.12/ 36,598	390	Q0P571	MYLPF	Myosin regulatory light chain 2, skeletal muscle isoform	3298	4.87/ 14,602	4.88/ 19,010
249	Q9XSC6	CKM	Creatine kinase M-type	2068	8.01/ 41,484	6.63 /42,989	245	Q5EA88	GPD1	Glycerol-3-phosphate dehydrogenase [NAD(+)], cytoplasmic	1463	7.88/ 42,000	6.42/ 37,648
	Q5EA88	GPD1	Glycerol-3-phosphate dehydrogenase [NAD(+)], cytoplasmic	1475		6.42/ 37,648		Q2KJJ9	FBP2	Fructose-1,6-bisphosphatase isozyme 2	449		7.52/ 36,767
218	Q3ZC09	ENOB_BOVIN	Beta-enolase OS=Bos taurus	9527	9.17/ 48,296	7.60 /47,096							
	Q9XSJ4	ENO1	Alpha-enolase	4021		6.37 /47,326							
	Q3T0P6	PGK1	Phosphoglycerate kinase 1	1453		8.48/ 44,538							
181	P10096	G3P_BOVIN	Glyceraldehyde-3-phosphate dehydrogenase	379	9.60/ 59,368	8.51/ 35,868							
88	Q3ZBT1	TERA	Transitional endoplasmic reticulum ATPase	1603	4.98/ 85,600	5.13 / 89,330							
	Q0III9	ACTN3	Alpha-actinin-3	1514		5.31/ 103,151							
	Q3ZC55	ACTN2	Alpha-actinin-2	1300		5.31/ 103,779							

Comparisons are made across the table.

Table 5. Characteristic of carbonylated protein spots derived from beef from steers fed steam flaked corn with or without distillers grains at the same quality grade.

Spot ID	Protein ID	ABV	Protein	Score	PI/Mw experimental	PI/Mw theoretical	Spot ID	Protein ID	ABV	Protein	Score	PI/Mw experimental	PI/Mw theoretical
SFC - USDA Upper 2/3rd Choice Quality Grade													
Increased oxidative damage without DDGS							Increased oxidative damage with DDGS						
455	Q0P571	MYLPF	Myosin regulatory light chain 2, skeletal muscle isoform	94	4.87/ 14,602	4.88/ 19,010	456	P02584	PFN1	Profilin-1	238	9.25/ 14,472	8.46/ 15,057
390	Q0P571	MYLPF	Myosin regulatory light chain 2, skeletal muscle isoform	3298	4.87/ 14,602	4.88/ 19,010							
335	Q3SZX4	CA3	Carbonic anhydrase 3	3126	9.46/ 28,237	7.71/ 29,370							
239	Q5KR49	TPM1	Tropomyosin alpha-1 chain	466	3.57/ 43,111	4.69/ 32,695							
	Q5KR48	TPM2	Tropomyosin beta chain	294		4.66/ 32,837							
179	P31800	UQCRC1	Cytochrome b-c1 complex subunit 1, mitochondrial	951	5.98/ 59,368	5.94/ 52.736							
SFC – USDA Select Quality Grade													
Increased oxidative damage without DDGS							Increased oxidative damage with DDGS						
100	P79334	PYGM	Glycogen phosphorylase, muscle form	1870	8.73/ 76,945	6.65/ 97,293							
109	P20004	ACO2	Aconitate hydratase, mitochondrial	518		7.87/ 85,359							

Comparisons are made across the table.

SFC without DDGS diet resulted in more oxidative damage within the USDA Select beef, as well, when compared to USDA Select beef from diets containing SFC and DDGS. In this study, the effects of DDGS in SFC diets are contrary to the effects of DDGS in DRC diets, indicating the need for further investigation.

Conclusions

USDA Upper 2/3rd Choice beef was more tender and generally had increased oxidative damage in proteins, compared to USDA Select beef. This gives credence to the hypothesis that there is a relationship between marbling and tenderness which may be mediated through oxidative damage to proteins. Conflicting results were observed on the effects of DDGS when comparing DRC-based diets to SFC-based diets.

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The Relationship of Liver Abscess Scores and Early Postmortem Meat Tenderness

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Summary with Implications

Acidosis is one of the most common nutritional disorders found in commercial feedlots. Cattle diets with high concentrations of starch can cause rapid production of acids in the rumen, disrupting microbial fermentation, causing liver abscess formation, and lowering livestock performance. This study was conducted to evaluate the relationship between the occurrence of liver abscesses and beef tenderness early postmortem. Results showed numerically lesser shear force values (greater tenderness) in loins from animals without liver abscesses, however, this was not statistically significant for slice shear force or Warner-Bratzler shear force. Although the effects of liver abscess occurrence in relation to meat quality are still unclear, results from this study provide a conceptual foundation for additional research to be explored on meat quality.

Introduction

The use of starch-based diets during the cattle finishing stage increases production of acids and can promote acidosis, the lowering of pH within the rumen due to highly fermentable grains. This results in reduced feed intake and increased liver abscesses, costing the United States' cattle industry millions of dollars in liver condemnations. Recent studies have suggested increased ruminal biohydrogenation in high energy (*grain-based*) diets which can increase unsaturated fatty acid deposition in muscle tissue. Elevated unsaturated fatty acd content has been linked to increased tenderness in beef during early postmortem aging. Additionally, the literature has presented a decrease in carcass performance and meat quality attributes (marbling scores) in cattle with increased liver abscesses. Therefore, an investigation into high energy diets and the occurrence of liver abscesses from cattle fed with and without the inclusion of a feed additive, across beef carcasses of similar marbling scores (quality grade), may increase the understanding of meat quality as it relates to different nutritional strategies and liver abscess occurrences.

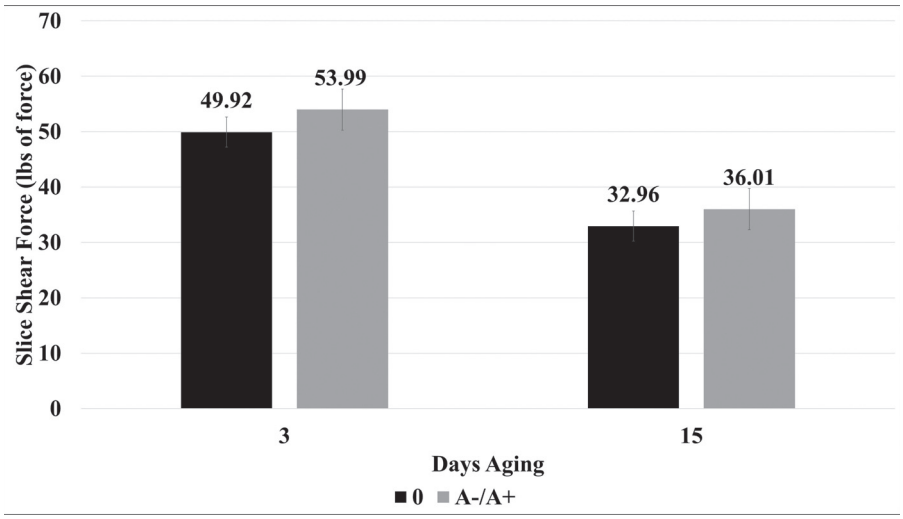

Figure 1: Analysis of Slice-Shear Force (kg on loins from carcasses with no abscesses (0) or moderate to high abscess scores (A-/A+) across 3 and 15 days of wet aging. [SEM (lbs of force): 0 = 2.706; A-/A+ = 3.718]

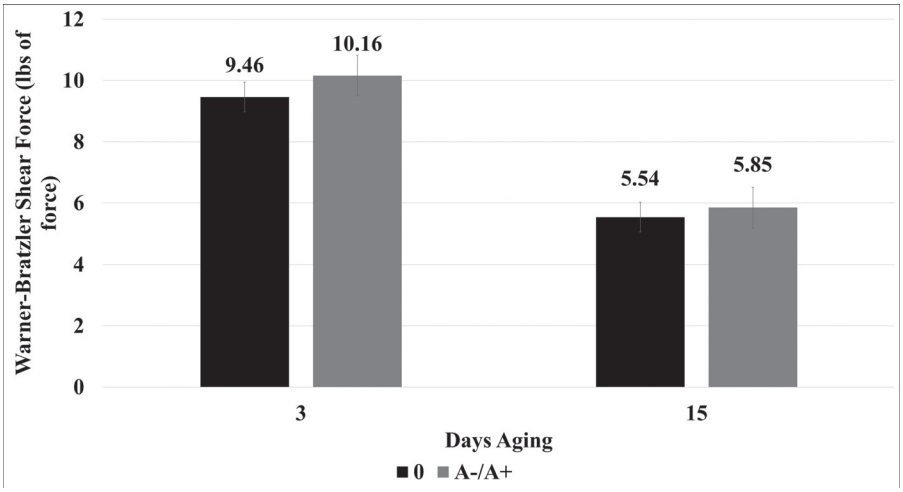

Figure 2: Analysis of Warner-Bratzler Shear Force (kg) on loins from carcasses with no abscesses (0) or moderate to high abscess scores (A-/A+) across 3 and 15 days of wet aging. [SEM (lbs of force): 0 = 0.484; A-/A+ = 0.66]

Procedure

Carcasses from cattle treated with or without Tylosin (Tylan 40®; Elanco Animal Health) were evaluated for occurrence of liver abscesses, with each carcass denoted with a score for liver abscesses. The scoring used was as follows: 0, no liver abscesses; A-, on or very few small abscesses; A, 1 large or a few small abscesses; A+, many large abscesses. Twenty-three Low Choice graded strip loins were collected, and separated based off of the following selection of No abscess occurrence (0, n = 15) or moderate to high abscess scores (A-/A+, n = 8). Abscess scores of A- defined 1 to 2 abscesses less than 2 cm in diameter and scores of A+ indicated 1 or more abscesses greater than 4 cm in diameter or greater than 4 small abscesses . Loins were split and randomly assigned to wet age for 3 or 15 days postmortem. After aging, 1 inch thick steaks were cut and measured for internal temperature and weight prior to cooking. Aged steaks were cooked to a target temperature of 160°F on a Belt Grill. After cooking, internal temperature and weight were recorded. Single cooked slices of steaks from both aging periods (n = 46) were cut parallel to the orientation of muscle fibers, and evaluated for Slice-shear force (SSF) using a Food Texture Analyzer with a Slice-shear blade. Then, steaks were individually bagged and stored overnight at 36°F for Warner-Bratzler shear force (WBSF) analysis. The following day, six ½ inch diameter cores were removed using a drill press, with each core being parallel to the orientation of the muscle fibers. Cores were sheared using a Food Texture Analyzer with a Warner-Bratzler blade. Peak WBSF values from each core were incorporated into a mean WBSF value for each steak. Slice shear force and average WBSF values for each steak were calculated for statistical analysis. Both SSF and WBSF values were analyzed as a completely randomized design with day of aging as a split-plot. Loin was considered the experimental unit (n = 23). Data were analyzed using the PROC GLIMMIX procedure of SAS 9.4 program with $\alpha \leq 0.05$ set for statistical significance.

Results

Neither SSF (Figure 1) nor WBSF values (Figure 2) were significantly different (P = 0.28 and 0.39, respectively) across treatments for both 3 and 15 days of aging. Interestingly, lower numerical values for shear force were found in loins from carcasses without liver abscesses compared to those from cattle with moderate to high liver abscess scores across both SSF and WBSF analyses. As expected, aging had an effect on SSF and WBSF, as loins aged 15 days exhibited lower shear force values ($P < 0.0001$) than loins aged 3 days. No treatment-by-aging effect was seen in either SSF ($P = 0.88$) or WBSF ($P = 0.74$). Either development of liver abscesses does not create sufficient metabolic stress to impact meat tenderness or the relatively low number of samples in this study limited the extent to which an effect could be detected.

Conclusions

Although there was a numerical trend supporting the hypothesis that metabolic changes as a consequence of liver abscess development might negatively impact meat tenderness, results were not statistically significant. There are very good reasons to control liver abscesses but it does not appear that meat quality is one of them.

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The Impact of Oxidative Stress on Postmortem Meat Quality

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Summary with Implications

This study was conducted to evaluate the relationship between animal oxidative status, using lipopolysaccharide (LPS) as a promoter for oxidation. This was used as a model to evaluate tenderization and meat quality factors early postmortem. Lambs were administered an intravenous injection of either saline, 50 ng/kg bodyweight (LPS50), or 100 ng/kg bodyweight (LPS100) every 72 hours for a 9-day period to stimulate physiological oxidative stress. After a day of rest, lambs were harvested, and pre-rigor Longissimus dorsi muscles were obtained for transcriptomic analysis. Loins, aged for 1 and 14 days, were analyzed for attributes relating to oxidative potential, meat tenderness, color, and lipid stability. Results show lambs administered lipopolysaccharide treatments exhibited greater oxidative potential, as indicated by increased rectal temperatures, and upregulated expression of mRNA protein pathways essential for cellular differentiation, proliferation, and apoptotic events. Lambs administered LPS50 tended to be more tender early postmortem, with significantly increased proteolysis (Troponin T). Interestingly, LPS treatment was not detrimental to meat quality, as indicated by more ideal color values and no significant changes in lipid oxidation. These data indicate that oxidative potential via oxidative stress can potentially increase tenderization early postmortem, which may provide more tender meat with no detriment to other meat quality factors.

Introduction

Tenderness is repeatedly cited as the primary element associated with both eating quality and consumer purchasing decisions. Inconsistent meat tenderness and its impact on consumer satisfaction is an obstacle to optimizing demand for U.S. meat products. Thus, investigations into the process of postmortem tenderization and the role of cellular organelles and mechanisms involved have strong, practical application.

Recent research using beef muscles with little aging has identified different oxidized proteins across different tenderness group. The tender (~3.9 kg) samples, compared to the intermediate (~5.3 kg) and tough (~7.6 kg) groups, had highly oxidized structural, contractile, and regulatory proteins, all directly associated with muscle contraction and tenderization mechanisms. Predisposition to oxidative stress may promote an increase in oxidized proteins.

It is hypothesized that states of oxidative stress may activate proteolytic mechanisms responsible for the structural degradation of muscle proteins during postmortem tenderization. The influence of oxidative stress is also being investigated for its impact on other factors of meat quality, such as lipid oxidation and color stability.

We hypothesized that controlled levels of oxidative stress modify mechanisms responsible for meat quality. The objectives of the research were to understand the mechanism related to meat quality in lamb from wethers administered defined levels of an oxidative stress promoter (lipopolysaccharides).

Procedure

A total of 29 lambs were individually housed and fed a standard finishing ration. Lambs were blocked by weight and randomly assigned to one of three intravenous injection treatments: Saline Control (n =10), 50 ng lipopolysaccharide O111:B4/kg bodyweight [LPS50] (n = 9), or 100 ng LPS O111:B4/kg bodyweight [LPS100] (n = 10). Each lamb was injected with 2 mL every 72 hours, totaling 3 injections across a 9-day challenge. Rectal temperatures were taken at 0, 1, 2, 4, 8, 12, 24, 48, and 72 hours post-injection times. After the immune challenge, lambs were given 48 hours lairage and then harvested. Pre-rigor loin muscle (80 mg) from Control and LPS100 lambs was obtained for transcriptomic analysis, evaluation of mRNA pathways as they relate to muscle development and function. After 1 or 14 d of aging, 1-inch thick chops were cut from the Longissimus dorsi for measuring tenderness (shear force), objective color, subjective discoloration, and lipid oxidation (TBARs). Samples were obtained to evaluate calcium concentration, fatty acids, sarcomere length, pH, proximate composition, proteolysis (Troponin-T; Desmin), and isoprostane content. Chops used for color analysis and TBARs were overwrapped with oxygen permeable film and placed under retail display (RD) for 7 d at 37°F. Chops for sarcomere length, proximate composition, and isoprostane content were analyzed at 1 d postmortem. Transcriptomics was measured using log fold change (total gene expression) and z-score (upregulated pathway, positive – LPS100, negative – Control). Tenderness was measured using the Warner-Bratzler shear force (WBSF) method and proteolysis was determined using protein electrophoresis and immunoblotting. Sarcomere length was measured via laser diffraction, free Ca^{2+} concentration was analyzed via inductively coupled plasma spectroscopy following high-speed centrifugation, and pH was measured via pH meter. Fatty acid profile was measured via gas chromatography. Isoprostane content was evaluated using an ELISA test kit, with final values calculated as picograms/mL. Proximate composition (%) included: fat content via ether extraction, moisture and ash via Thermogravimetric Analyzer, and protein content was calculated by difference. Lipid oxidation, Thiobarbituric acid reactive substances (TBARs), was measured

Table 1. Transcriptomics expressed by Conical Pathways in Contol vs 100ng LPS treated lambs. P-values for negative logarithmic (-log) expression set for (P_{raw} < 0.05).

Function	Pathways	Fold change -log	Z-score
Cell Biosynthesis and Turnover	IGF-1	2.9	0.707
	EGF	2.6	0.816
	ErbB2-ErbB3	2.24	-0.447
	ILK	2.05	1
	cAMP	1.88	-0.302
	PI3K	1.63	1.414
	ERK5	1.46	1.342
	Ceramide	0.848	1.89
Nucleic Modification	Unfolded Protein	5.93	0.378
	Telomerase	3.43	0.707
	HMGB1	2.5	1.414
	EIF2	1.94	0.333
	Neurotrophin/TRK	1.91	0.816
	JAK/Stat	1.81	0.816
Oxidative Response/ Autophagy	NRF2 Oxidative Stress Resp.	6.48	1.265
	IL-6	3.49	-0.905
	p38 MAPK	3.09	1
	Sumoylation	2.35	1.633
	TNFR-2	2.19	2
	CXCR4	2.01	0.707
	IL-8	1.52	0.632
	NO/ROS prod. In Macrophages	1.31	0.333
	IL-3	1.31	1.342
Muscle Function Oxidative-Stress	eNOS Signaling	2.63	-2.121
	Agrin	1.84	1.342
	Calcium Signaling	1.81	-1.633
	PPARα/RXRα	1.65	-1.265
	D-myo-inositol-tetrakiphosphate	1.59	0.707

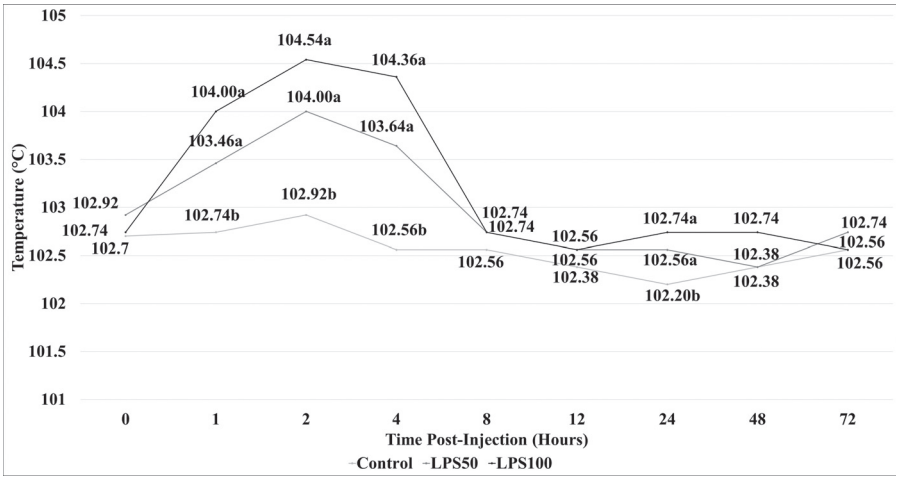

Figure 1. Rectal temperatures of lambs administered intravenous injections of Control, LPS50, or LPS100. Superscripts denote statistical differences (P < 0.05) within hours.

by the amount of mg of malonaldehye per kg of muscle tissue following retail display periods of 0 or 7 d. Instrumental color was measured using a colorimeter to detect lightness (L*), redness (a*), and yellowness (b*). Subjective discoloration was also evaluated daily during retail display by a panel of five trained panelists using a percentage scale where 0% meant no discoloration and 100% meant total surface discoloration.

Statistical analysis was conducted with SAS (version 9.4, Cary, NC). Transcriptomic data were quality trimmed using Trim Galore!, and aligned to the Oar_rambouillet_v1.0 reference genome STAR (Dobin et al., 2016). Differential expression (control vs LPS 100) was evaluated using transcript counts in DESeq2 (Love et al., 2014). Loci with P_{adj}<0.05 were considered to be differentially expressed; those with P_{raw}<0.05 were utilized for pathway exploration in Ingenuity Pathway Analysis (Qiagen). Objective and subjective color data were analyzed as a split-plot repeated measures design with treatment as the whole-plot, aging period as the split-plot and retail display as the repeated measures. Tenderness, troponin-T, desmin, calcium, and pH were analyzed as a spilt-plot design with treatment as the whole-plot and aging period as the split-plot. Lipid was evaluated using free thiols and carbonyls were a split-split-plot design with treatment as the whole plot, aging period as the split-plot and retail display time as the split-split-plot. Sarcomere length, fatty acids, and isoprostanes were analyzed as a completely randomized design. Lamb was the experimental unit. Data were analyzed using the PROC GLIMMIX procedure of SAS and animal was the experimental unit. Correlations were evaluated using the PROC CORR procedure of SAS across all postmortem analyses. All means comparing within aging periods were separated using SLICE function in SAS. All means were separated using the LS MEANS statement with an α level of 0.05 and tendencies were considered at an α level of 0.15.

Results

Treatment affected rectal temperatures (Figure 1). Lambs administered LPS treatments exhibited an increased ($P \leq$ 0.02) rectal temperature at 1, 2, 4, and 14 h

Table 2. Analytical measures of 1 and 14 day aged chops from lambs administered Saline Control, LPS50, or LPS100. Superscripts denote statistical differences ($P < 0.05$).

	Treatment										
	Days Aging										
	1				14				*P*-value		
	Control	LPS50	LPS100	*P*-value	Control	LPS50	LPS100	*P*-value	Trt	Age	Trt*Age
WBSF, lbs of force (kg)	17.73 (8.06)	14.50 (6.59)	15.99 (7.27)	0.10	6.09 (2.77)	5.32 (2.42)	5.19 (2.36)	0.9	0.11	< 0.0001	0.13
pH	5.71	5.68	5.73	0.54	5.84	5.86	5.91	0.27	0.13	< 0.0001	0.76
Calcium (µm)	46.72	40.71	43.63	0.33	108.02	104.51	103.12	0.41	0.50	< 0.0001	0.88
Troponin-T Degradation (%)	6.85b	10.32a	6.24b	0.02	47.73	49.19	41.68	0.78	0.27	< 0.0001	0.88
Desmin Degradation (%)	3.01	4.17	3.54	0.85	55.02	41.73	54.94	0.1	0.15	< 0.0001	0.08

LPS: Lipopolysaccharides

WBSF: Warner-Bratzler Shear Force

[a,b] Means within an aging period with different superscripts are different ($P < 0.05$).

post-injection, as the increase in LPS content increased the temperature at these time points. Rectal temperature is an indicator of acute physiological inflammation, suggesting increased oxidative stress occurred.

Transcriptomics is an analytical method that identifies molecules that have been transcribed from genes into RNA. These protein precursors can provide the cellular instructions for synthesis of specific proteins, which can be associated with particular metabolic pathways. For this experiment, transcriptomic analysis identified different gene expressions across Control and LPS100 treated lambs ($P_{raw} < 0.05$) (Table 1). In particular, pathways with positive z-scores denote increased expression of pathways for LPS100 lambs. Increased expression in LPS100 treated lambs primarily focus on RNA responsible for cellular biosynthesis and turnover, nucleic modification, oxidative stress response systems, and muscle functionality and apoptotic activation. Given the impact oxidative potential can have on cellular damage and dysfunction, it is reasonable to expect that lambs treated with a compound such as LPS that triggers an immune and oxidative response would induce pathways responsible for cellular death and turnover. Additionally, the increase in oxidative stress-related pathways link the concept between increased oxidative stress with muscle response systems, which could impact meat quality. Negative z-scores denote an increased expression in pathways as they relate to Control samples. This analysis validates the occurrence of oxidative stress.

Treatment tended to affect shear force ($P = 0.1343$) values [Table 2]. In particular, LPS50 and LPS100 chops aged 1 day postmortem tended to have a lower shear force compared to the control (14.50 lbs, 15.99 lbs, and 17.73 lbs of force, respectively).

Proteolysis of troponin-T and desmin were utilized as indicators of protein degradation. During tenderization, proteolytic enzymes break down different proteins related to structures within the sarcomere and myofibril, reducing shear force and improving tenderness. There was no treatment main effect on desmin, however, a treatment-by-days of aging trend ($P = 0.08$) was identified, as LPS50 chops tended to have a lower percent degradation compared to Control and LPS100 chops at 14 days aging (41.73%, 55.02%, 54.94%, respectively), with no impact at 1 day of aging. A treatment effect was found at 1 day aging for troponin-T analysis ($P = 0.02$), as LPS50 samples were higher in percent degradation compared to Control and LPS100 (10.32%, 6.85%, 6.24%, respectively). A days of aging effect was found, as 14 days aging had significantly ($P < 0.0001$) greater percent degradation compared to day 1 aged chops. This indicates LPS50 treated lambs exhibited greater degradation early postmortem compared to the other treatments.

Days of aging had an effect on free Ca^{2+} concentration ($P < 0.0001$). Chops aged for 14 days exhibited higher amounts of free calcium concentration than chops aged for 1 day postmortem. However, no LPS treatment effect was observed for free Ca^{2+} concentration ($P = 0.33$). Calcium plays a critical role in the tenderization of meat postmortem. Calcium acts as a regulator for muscle contraction in live tissue, but functions to activate proteolytic enzymes in meat postmortem. Free Ca^{2+} concentration was measured as an indicator of proteolytic enzyme activity, since the increase in Ca^{2+} would activate proteolytic enzymes used to breakdown muscle proteins (Troponin-T, Desmin). However, the lack of statistical differences in Ca^{2+} concentration does not explain observed differences in tenderness.

There was no LPS treatment effect on pH ($P = 0.27$). A higher pH would allow greater water retention and stearic hindrance between muscle structures, facilitating an increase in tenderness. Days of aging had an effect on pH ($P < 0.0001$), as chops aged 14 days increased their pH compared to 1 day aged chops. However, the increase in pH was not within the range recognized for dark cutting meat (≥ 6.0), meaning that the increase to pH was not seen as a detrimental aspect to meat quality.

Sarcomere length and proximate composition were measured as potential indicators of meat tenderness (Table 3). Typically, a longer sarcomere length and greater moisture and fat content are associated

Table 3. Analytical measures of 1 day aged chops from lambs administered Saline Control, LPS50, or LPS100.

	Treatment			
	Control	LPS50	LPS100	*P*-value
Sarcomere Length (μm)	1.7	1.73	1.71	0.7
Moisture (%)	75.1	75.51	75.45	0.31
Protein (%)	15.13	14.43	13.91	0.68
Fat (%)	8.18	8.29	8.99	0.82
Ash (%)	1.59	1.77	1.66	0.44
SFA (mg/100g tissue)	3,289	3,301	3,560	0.86
MUFA (mg/100g tissue)	4,100	4,139	4,542	0.77
PUFA (mg/100g tissue)	738	810	839	0.82
Trans Fatty Acid (mg/100g tissue)	365	346	419	0.55
Total (mg/100g tissue)	8127	8250	8941	0.82
Isoprostane Content (pg/mL)	165.51	239.51	219.95	0.2

LPS: Lipopolysaccharides

SFA: Saturated Fatty Acids

MUFA: Monounsaturated Fatty Acids

PUFA: Polyunsaturated Fatty Acids

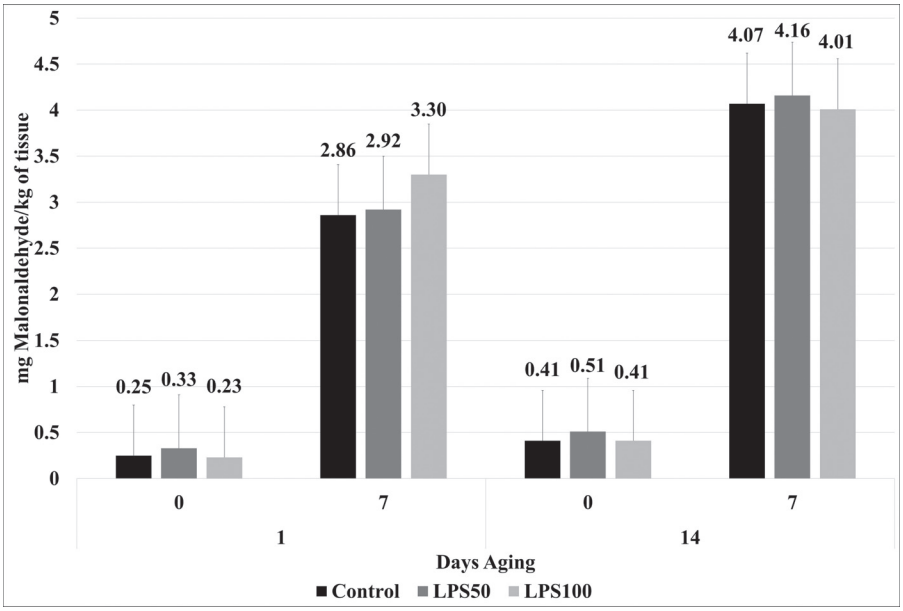

Figure 2. Lipid Oxidation (Thiobarbituric acid reactive substances) for 1 and 14 days aged chops after 0 and 7 days of retail display from lambs administered Saline control, LPS50, or LPS100.

with greater tenderness. LPS treatments, however, had no effect on sarcomere length and proximate composition.

Fatty acid profiles were measured as a potential confounding variable on meat quality. Composition of fatty acids found within muscle are critical when examining tenderness, as recent literature has associated an increase in unsaturated fatty acids (UFAs) with increased tenderness early postmortem. Additionally, fatty acids impact color and lipid oxidation, with increased UFA content associated with increased discoloration and lipid oxidation in muscle tissue, negatively impacting meat quality. Fortunately, there were no differences among any fatty acid attributes across treatments, suggesting that fatty acid composition was not the source of differences in tenderness across treatments.

There was no treatment effect ($P = 0.20$) found for isoprostane content. Isoprostanes are regarded as one of the best biomarkers available to detect sustained oxidative stress in a tissue. Isoprostanes are generated during oxidation of arachiodonic acid (20:4) via reactive oxygen species, constituents of oxidative stress. The generation of isoprostane content can be used as an indicator of oxidative stress damage produced in a living system, and used to telegraph the degree of oxidative damage which has occurred in a sample. While not significant, it was interesting to see that both LPS50 and LPS100 treatments had a numerically greater isoprostane content compared to the Control (239.51 pg/mL, 219.95 pg/mL, and 169.51 pg/mL, respectively), suggesting an increase in LPS-induced oxidative stress in those samples.

Lipid oxidation was determined as an indicator of oxidation or rancidity of meat. LPS had no effect on lipid oxidation ($P = 0.9687$). The TBARs values displayed in Figure 2 show a day effect ($P < 0.0001$), as 7 days of RD significantly increased oxidation compared to 0 days of RD. A potential trend ($P = 0.06$) occurred during aging, as 14 day aged chops tend to increase in lipid oxidation compared to 1 day aged chops. While there was no days of aging-by-days of RD interaction ($P = 0.1786$), all samples aged 14 days exhibited the greatest numerical amount of oxidation at 7 days of RD compared to all other measures. From these comparisons, it is noteworthy that LPS treatments did not induce greater oxidation of muscle tissue, which relate to extreme off-flavors or detrimental effects on quality.

Color is the primary factor associated with consumer purchasing decisions, as consumers use visual evaluation of meat quality when product is sold. Consumers desire a bright cherry-red color in meat. Objective color measures include lightness score, L* (0 = black, 100 = white), redness score, a* (-60 = green, 60 = red), and yellowness score, b* (-60 = blue, 60 = yellow). As seen in Table 4, the L* values decreased as days of RD increased for both aging periods, however, the L* values were significantly lighter in LPS100 samples compared to Control ($P = 0.0017$). The a* values had an LPS treatment-by-days of aging interaction ($P = 0.0008$). In total, 14 day aged chops had greater a* values

Table 4. Instrumental color (L*, a*, b*) and discoloration (%) of 1 and 14 days aged chops from lambs administered Saline Control, LPS50, LPS100. Different superscripts denote differences ($P < 0.05$) within row.

		Treatment			*P*-value		
Measure	Days of Aging	Control	LPS50	LPS100	*Trt*	*Age*	*Trt x Age*
L*	1	44.37	45.47	45.92	0.0017	0.68	0.92
	14	44.36	45.73	46.06			
Mean		44.37[b]	45.6[ab]	45.97[a]			
a*	1	13.7[a]	13.67[a]	13.31[a]	0.01	<.0001	0.0008
	14	15[b]	16.01[a]	15.7[a]			
b*	1	6.93[c]	8.2[a]	7.39[bc]	0.12	0.12	0.02
	14	7.88[a]	7.55[a]	8.04[a]			
Discoloration	1	7.81[a]	3.34[a]	9.27[a]	0.35	0.22	0.02
	14	16.43[a]	3.32[b]	5.58[b]			

[a,b] Superscripts denote differences (P < 0.05) within a trait.

LPS: Lipopolysaccharides

compared to 1 day aged chops. Within 14 day aged chops, chops from both LPS treatments had significantly greater a* scores, denoting greater redness stability compared to the Control. The b* values had an LPS treatment-by-days of aging interaction ($P = 0.02$), as 14 day aged chops had greater b* values compared to 1 day aged chops. Within 1 day aging, LPS50 chops had the highest b* score compared to the other treatments, denoting a greater degree of yellowness within the samples. As a result, chops from the LPS treated lambs exhibited had greater color stability compared to control samples.

Conclusions

The results suggest that LPS-induced oxidative stress *in vivo* could explain the trend of increased tenderness and the significant increases in proteolysis early postmortem for LPS-treated lambs, in particular LPS50 treated lambs. Additionally, the increased oxidative stress was not detrimental to meat color or lipid oxidation, suggesting that low levels of oxidative stress alter meat tenderization early postmortem, without negatively impacting other meat quality attributes.

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Accelerated Dry Aging under Anaerobic Conditions

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Summary with Implications

The purpose of dry aging is to develop novel flavors and other sensory characteristics different from wet aged meat. However, leaving meat exposed to air for an extended period of time can have negative effects on meat quality. As the meat is exposed to oxygen for an extended period of time, lipids are oxidized resulting in compounds that negatively affect flavor. In this study, oxygen concentration was regulated along with time, temperature, humidity, and air flow. The purpose of oxygen regulation was to determine the effect of oxidation on the quality, specifically flavor preference, of dry aged meats. Sensory analysis via untrained panelists detected no flavor differences between traditionally dry aged meat and meat dry aged in anaerobic conditions, despite anaerobic dry aged samples having lower lipid oxidation values. Further sensory analysis via highly trained panelists is being conducted to determine if lipid oxidation affects dry aged beef flavor.

Introduction

Dry aged beef is marketed as having improved flavor, although the causes of dry aged flavor are still not fully understood. Additionally, while the flavor of dry aged beef may be more intense, whether or not it is improved relies solely on the preferences of the consumer. The two likely causes of "dry aged flavor" are: 1) the concentration of flavor compounds as the meat loses moisture, and 2) the development of new flavors via enzymatic and oxidative processes.

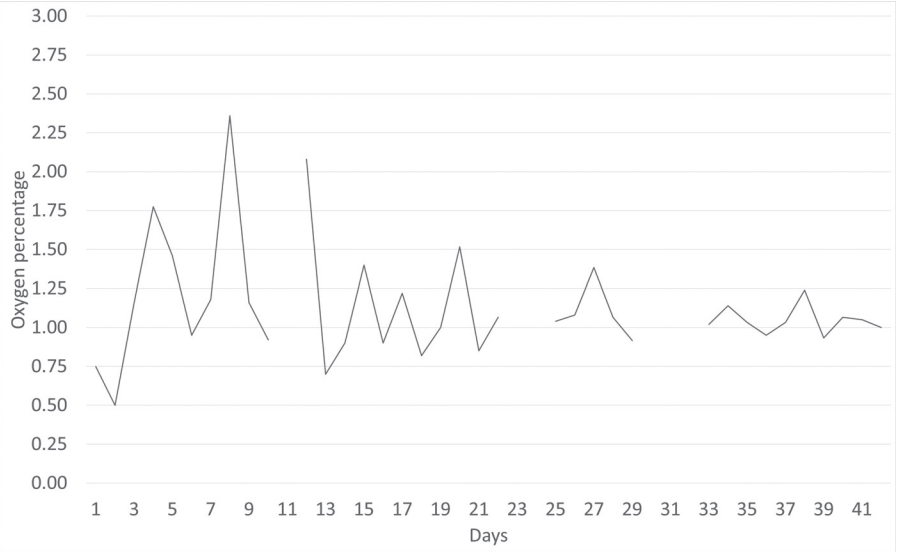

Figure 1. Average oxygen percentage in anaerobic dry aging chambers over time.

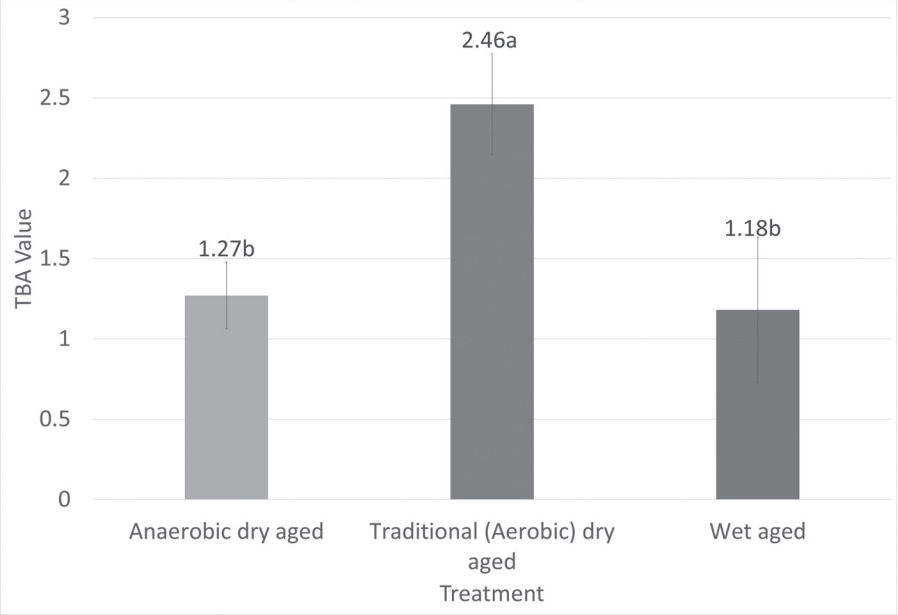

Figure 2. Lipid oxidation measurements via thiobarbituric acid reactive substances (TBARS) of anaerobic dry aged, traditional (aerobic) dry aged, and wet aged loins.

Lipid oxidation is a natural process that occurs when meat is exposed to oxygen. The oxidation of lipids results in secondary reactive products that negatively affect meat flavor. The objective of this research was to determine the effects of lipid oxidation on

Table 1. Moisture loss, trim loss, final weight and final yield of wet and dry aged loins.

	Dry Aging Treatment			
Trait	Anaerobic	Traditional (Aerobic)	Wet	SEM[c]
Moisture loss during aging (lbs.)	3.48[a]	3.35[a]	0[b]	0.17
Trim loss (lbs.)	3.02[a]	3.04[a]	0.71[b]	0.12
Total weight loss (lbs.)	6.53[a]	6.42[a]	0.71[b]	0.29
Final weight (lbs.)	7.96[a]	7.50[a]	13.38[b]	0.30
Final yield (%)	55%[a]	54%[a]	95%[b]	0.04

[a-b] Means in the same column with different superscripts are different (P<.05)

[c] Standard error of the means.

Table 2. The number of panelists preferring anaerobic or traditional (aerobic) dry aged loins by day of sensory test.

	Sensory day		
Preference	Day 1	Day 2	Total
Anaerobic dry aged	12[a]	19[a]	31[a]
Traditional (Aerobic) dry aged	14[a]	10[a]	24[a]

[a] Means in the same column with different superscripts are different (P < .05)

the flavor of dry aged beef. The hypothesis of this project was that dry aging meat in anaerobic conditions would inhibit lipid oxidation, resulting in the absence of the negative flavor compounds associated with lipid oxidation and ultimately a superior dry aged product.

Procedure

Eighteen USDA upper 2/3 Choice boneless strip loins were assigned to one of three treatments: wet aging, traditional (aerobic) dry aging, or anaerobic dry aging. All strip loins were aged for 41 days, not including aging at the processing facility. The dry aged samples were held at 50% relative humidity (RH) with a fan speed of 2,200 revolutions per minute (RPM) and a constant temperature (37°F). The wet aged samples were retained in the original vacuum sealed packages from the processor and were held in the same cooler as the dry aged samples. After aging, the dry aged loins were trimmed of all dehydrated lean and fat, fabricated into steaks, evaluated for trim loss and final weight, and separated for further analyses. Further analyses included sensory analysis, and lipid oxidation via the thiobarbituric acid reactive substances (TBARS) assay.

The aerobic dry aged loins were aged in aging chambers exposed to normal atmospheric conditions (ca. 21% oxygen). A computer system regulated relative humidity at 50% and monitored weight loss during the aging period. Anaerobic dry aged loins were aged in aging chambers that were enclosed in oxygen impermeable film. Tubing connecting the chambers to the various components of the system was also oxygen impermeable. The various components of the system include an air pump to circulate the air in the system, silica gel filled columns to control relative humidity, and an oxygen scavenger column in which food grade oxygen scavengers were regularly replaced to help keep the oxygen concentration low. The system was not able to reach true anaerobic conditions, but the oxygen concentration was kept below 1.5% with a few minor peaks during the 41-day aging period. Oxygen concentration during aging is presented in Figure 1. Several gaps in the data can be noted in the graph; this was due to a computer error where the system continued to run but failed to report the data. No spikes in oxygen concentration occurred at those times. The anaerobic systems were flushed with a gas mixture consisting of 80% nitrogen (N) and 20% carbon dioxide (CO_2) at the start of aging and again if the oxygen concentration approached 4%. Relative humidity was controlled by the system, whereas weight loss and oxygen concentration were only monitored.

A paired preference test was conducted to determine consumer flavor preference between anaerobic and traditionally (aerobic) dry aged steaks. Panelists were served two samples and asked to identify the sample whose flavor they most preferred. The first day compared the first three loins of each dry age treatment and the second day compared the last three loins. Sensory steaks were cooked to medium well (158°F) and then cut to a sample size of 2 cm × 1 cm × 2.54 cm. Each sample was given a random, unique 3-digit number and served to 25–30 panelists. Panelists received no training prior to the analysis.

Lipid oxidation (TBARS) was measured to compare differences in the level of lipid oxidation based on aging method. Measurements reflect the amount of thiobarbituric acid reactive substances in the lean portion of the sample. External fat was removed prior to TBARS analysis.

Standard tables were used to determine the significance of the paired preference test. All other data were analyzed as a randomized complete block.

Results

Wet aged loins, as expected, had lower weight loss during aging, less trim loss, and overall higher yield as shown in Table 1. There were no significant weight loss or trim loss differences between the two dry aging methods.

Sensory analysis was conducted for the aerobic and anaerobic dry aging methods. The panelists found no difference between the two samples ($P < .05$, Table 2). This may have occurred through sampling of lean only. Much of the oxidation during aerobic dry aging occurs within the subcutaneous fat.

Results from the TBARS assay showed that there was a significant difference between the anaerobic and aerobic dry aged treatments as shown in Figure 2. Anaerobic samples had a level of oxidation similar to that of wet aged samples. Aerobic dry aging oxidation levels were nearly double the levels of both wet and anaerobically dry aged samples.

Further research via trained panelists is being conducted to determine if the

differences in oxidation levels significantly affect flavor.

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Pseudomonas Survive Thermal Processing and Grow during Vacuum Packaged Storage in an Emulsified Beef System

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Summary with Implications

New research has suggested the ability of Pseudomonas*, a common spoilage microorganism, to grow in cooked beef products stored under vacuum which challenges the traditional understanding of the role of* Pseudomonas *during cooked beef spoilage. Understanding the mechanisms of survival and growth of* Pseudomonas *in these products is crucial for improving shelf life. The objective of this experiment was to determine* Pseudomonas *survival in a thermally processed, emulsified cooked beef model system. After eight weeks of refrigerated storage,* Pseudomonas *was recovered from cooked emulsified beef, indicating the potential for* Pseudomonas *to survive thermal processing and cause spoilage in cooked vacuum packaged beef products.*

Introduction

Some *Pseudomonas* species, like *P. fragi, P. lundensis*, and *P. fluorescens*, are considered the predominant microbial spoilers of aerobically stored raw meat products, such as meat in overwrap packaging, with minor roles in vacuum packed meat product spoilage. Lactic acid bacteria have traditionally been understood to be the primary bacterial spoilers of vacuum packaged cooked meat products. Additionally, traditional understanding has been that *Pseudomonas* are not capable of growing in anaerobic environments. However, recent findings have challenged this principle and opened new avenues for research on the role of *Pseudomonas* in the spoilage of thermally processed vacuum packaged meat. Spoilage *Pseudomonas* can be found at all stages of animal agriculture and food processing suggesting the natural animal environment and contamination from the food processing environment could both contribute to the *Pseudomonas* presence in vacuum packed cooked beef product. Thermal processing in the meat industry is implemented to achieve product safety by reducing the pathogenic bacteria present in the raw meat and typically is not used to completely sterilize a product. Given the potential thermal resistance of *Pseudomonas*, populations that survive cooking may also be responsible for product spoilage. Therefore, an experiment was conducted to determine whether spoilage *Pseudomonas* can survive thermal processing and grow anaerobically through refrigerated storage in an emulsified model beef system.

Table 1. Concentration of *Pseudomonas* (log_{10} cfu/g ± SE) in emulsified beef during thermal processing and 39° F refrigerated storage (P < 0.01)

Sampling time	Uncooked Control	130° F Cooked	160° F Cooked
Inoculated raw beef	4.93 ± 0.05 [a]	5.01 ± 0.04[a]	5.06 ± 0.04[a]
After cooking or emulsifying (control)	4.75 ± 0.07[a]	0.18 ± <0.01[c]	0.18 ± <0.01[c]
14 days storage	3.73 ± 0.06[b]	0.44 ± 0.09[cde]	0.39 ± 0.09[cde]
28 days storage	3.81 ± 0.10[b]	0.23 ± 0.04[dc]	0.69 ± 0.21[e]
56 days storage	3.55 ± 0.17[b]	0.57 ± 0.25[de]	0.67 ± 0.24[e]

[a-e]Means within the table with different superscripts differ ($P < 0.05$)

Procedure

Three *Pseudomonas* isolates collected from spoiled meat were grown individually in Luria-Bertani broth for 48 hours at 89° F (32° C) and combined to create an inoculation cocktail (approx. 8 log_{10} colony forming units (cfu)/g). Coarse ground beef (4.4 lbs.) was inoculated by directly adding inoculation cocktail to the meat to approximately 5 log_{10} cfu/g of *Pseudomonas* and emulsified to form a frankfurter-like meat batter with ice, salt, sodium nitrite, sodium erythorbate, black pepper, and garlic in a Hobart Food Processor. Batter samples (ca. 20 grams, approx. 2 by 2 inches, and < 0.6 inch thickness) were vacuum packaged individually and packages were allocated into three treatments: two cooked treatments (heated to final temperatures of 160° F held for one second or 130° F held for 121 minutes) and one uncooked treatment. Samples were cooked in water baths using sous vide units to target internal temperatures and then chilled in an ice bath for 15 minutes. For the 130° F treatment, samples were placed in a 130° F water bath and upon reaching 130° F, held for 121 minutes. For the 160° F treatment, samples were placed in 145° F water bath for one hour, then moved to a 155° F water batch for 30 minutes, and then held in a 175° F water bath until reaching 160° F. Time-temperature combinations for cooking treatments were based on common thermal processing schedules used in the meat industry. After cooking, samples from all treatment groups were split into refrigerated storage at 39 and 50° F. *Pseudomonas* concentrations were determined after inoculation, after chilling for cooked samples and after emulsifying for uncooked samples, and at 14, 28, and 56 days of storage. At each sampling time, 10 grams of an individually packed sample were stomached with 20 grams of buffered peptone water. Homogenates were serially diluted and plated onto *Pseudomonas* Agar Base plates supplemented with Cetrimide-Fucidin-Cephalosporin Selective Supplement to solely determine the concentration of *Pseudomonas*. The experiment was

Table 2. Concentration of *Pseudomonas* (log_{10} cfu/g ± SE) in emulsified beef during thermal processing treatments and 50° F refrigerated storage (P < 0.01)

Sampling time	Uncooked Control	130° F Cooked	160° F Cooked
Inoculated raw beef	5.07 ± 0.04[a]	5.03 ± 0.03[a]	4.99 ± 0.02[a]
After cooking or emulsifying (control)	4.69 ± 0.04[a]	0.18 ± <0.01[d]	0.18 ± <0.01[d]
14 days storage	4.09 ± 0.19[b]	0.18 ± <0.01[d]	0.58 ± 0.17[ef]
28 days storage	3.75 ± 0.06[bc]	0.28 ± 0.04[de]	0.49 ± 0.04[def]
56 days storage	3.41 ± 0.16[c]	0.70 ± 0.27[f]	0.58 ± 0.23[ef]

[a-f]Means within the table with different superscripts differ ($P < 0.05$)

conducted in three independent replications with duplicate samples. Data were reported as log_{10} cfu/g and analyzed using the GLIMMIX procedure with LSD mean separation in SAS 9.4.

Results

Pseudomonas concentrations in uncooked treatments decreased by 1.39 log_{10} CFU/g ($P < 0.05$) during 39° F refrigerated storage (Table 1) and by 1.66 log_{10} CFU/g ($P < 0.05$) during 50° F refrigerated storage after 56 days (Table 2). In both cooked treatments at both storage temperatures, *Pseudomonas* concentrations were reduced below the detection limit (0.18 log_{10} CFU/g) immediately following cooking ($P < 0.05$). Those populations increased to > 0.5 log_{10} CFU/g after 56 days of storage ($P < 0.05$) in each cooking, storage temperature treatment combination. These results suggest that spoilage *Pseudomonas* may not be strictly aerobic and are potentially capable of causing spoilage in thermally processed beef products continuously stored in vacuum packaging when stored beyond 56 days. Additionally, final cooking temperature did not have an impact on the growth of *Pseudomonas*, indicating the ability of *Pseudomonas* to survive a range of thermal treatment processes used in the meat industry. As the emphasis to reduce food loss and waste increases in importance, the spoilage potential of *Pseudomonas* in vacuum packaged meat products must be considered.

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Evaluation of Biochar on Nutrient Loss from Fresh Cattle Manure

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Summary with Implications

An experiment was conducted to evaluate the impact of biochar and time on manure nutrient retention. Pans were used to simulate feedlot pens with 10 replications per treatment. Biochar was included at 0, 5, or 10% of manure dry matter with 30 and 60 day durations to evaluate pan contents over time. There was a 13-percentage unit increase in organic matter losses from day 30 to 60 for pans without biochar, and a 3-percentage unit increase for pans containing biochar. The least nitrogen loss was measured on the pans without biochar harvested at 30 days. Pans harvested at 60 days all had similar nitrogen loss. Phosphorus losses were not impacted by treatment while potassium losses decreased over time but were not impacted by biochar treatment. In this study biochar included at 5 and 10% of manure dry matter limited carbon losses but did not impact manure nutrient retention of nitrogen, phosphorus, or potassium.

Introduction

Biochar has been utilized as a soil amendment to improve soil nutrient content and crop-yield potential for many years. Biochar is produced by burning organic matter (OM; typically plant material) at high temperatures in the absence of oxygen and has vast applications. Recent studies have shown that when biochar is combined with livestock manure, manure nutrient retention (primarily in the form of nitrogen; N) is enhanced. Nutrient losses from feedlot manure, primarily ammonia, are both an environmental and economic concern. Retaining manure N and phosphorus (P) improves the value of manure for the producer when marketed as fertilizer. If excess nutrients in livestock manure are not retained, losses create challenges for air and water quality.

The objective of this study was to determine the impact of varying inclusions of biochar, when combined with feedlot soil and cattle manure, on manure nutrient retention and organic matter losses over time.

Procedure

A simulated feedlot pen study was conducted using 60 aluminum pans (10 × 9 × 2 inches) to represent the hard interface of a feedlot pen. Each pan was weighed and filled with a 60:40 blend of feedlot top soil and manure, respectively. Biochar was included at 0, 5, and 10% of manure dry matter (DM), and all contents of the pan were mixed to mimic the hoof action of cattle in a feedlot pen. A 3 × 2 factorial design was utilized, with biochar inclusion at 0, 5, or 10% of manure DM and samples harvested at 30 and 60 days with 10 replications per treatment. All pans were randomized onto 2 screened, metal shelving units located in a temperature-controlled room in the University of Nebraska-Lincoln Metabolism Lab (Lincoln, NE). Biochar, manure, and soil samples were analyzed for DM and nutrient content prior to study initiation.

Biochar was provided by High Plains Biochar (Laramie, WY) and was sourced from forest wood waste, primarily ponderosa pine trees. Biochar had a DM content of 97.5%, and on a DM basis carbon (C) content was 75.4%, with a surface area of 306 m^2/g, bulk density of 8.1 lb/ft^3, and pH of 8.45. Biochar particle size measured ≤ 2-mm for 72.3% of total sample, 22.7% of sample measured between 2- and 4-mm and the remainder measured >4-mm. Manure was sourced from a commercial feedlot near Mead, NE, that houses cattle in covered pens with slatted flooring. Slatted flooring allows for elevated manure and urine capture, with no soil contamination, therefore, producing a liquified manure slurry. Nutrient content of manure at a DM of 10.4% measured 72.8% OM, 5.87% N, 1.33% P, and 2.66% potassium (K) on a DM basis.

Original intent was to harvest thirty pans at 30 days after trial initiation and thirty pans at 60 days. Due to UNL research restrictions onset from COVID-19, thirty pans selected for harvest at 30-d were placed in plastic bags (to avoid cross-contamination), placed in a freezer, and were ground at a later date. Thirty pans selected for 60-d harvest, were harvested on d 52 of study and ground immediately, due to Phase 4 restrictions on UNL research.

At time of harvest, pans were weighed, and contents were ground through a 1-mm screen. Ground samples were sent to Ward Laboratories, Inc. (Kearney, NE), and analyzed for DM, OM, and nutrient (N, P, K specifically) content. Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.) with pan as the experimental unit.

Results

Nutrient losses from the manure:soil mixture are reported as a % of nutrients weighed into each pan on day 1 (Table 1). There was an interaction ($P = 0.05$) between biochar inclusion and day for OM loss. At the 30-day harvest there were no differences between treatments (9.12% OM loss). The biochar treatment was effective at limiting OM losses at 60 days, with the 10% biochar treatment being most effective. The pans with no biochar had an increase in OM losses of 13-percentage units from day 30 to day 60 while the pans with biochar had a 3-percentage unit increase.

A biochar inclusion by day interaction ($P < 0.01$) was observed for nitrogen losses. With no biochar, N losses increased 7 percentage units from day 30 to day 60. With biochar inclusion (both the 5 and 10% biochar treatments) N losses did not increase from day 30 to day 60. The least N loss was measured on the 0% biochar pans harvested

Table 1. Simple effects of biochar inclusion and time on manure nutrient loss

	Biochar 0%		Biochar 5%		Biochar 10%			*P*-Value		
	30d	60d	30d	60d	30d	60d	SEM	Inclusion	Day	Inclusion × Day
OM lost, %	7.50[b]	20.6[a]	9.94[b]	14.0[ab]	9.91[b]	11.8[b]	2.38	0.40	<0.01	0.05
N lost, %	26.3[b]	33.3[a]	34.8[a]	32.7[a]	37.9[a]	33.2[a]	1.85	0.01	0.96	<0.01
P lost, %	3.16	4.75	8.25	4.00	9.75	5.94	2.93	0.42	0.37	0.54
K lost, %	6.36[ab]	1.26[bc]	10.6[a]	0.22[c]	9.34[a]	3.06[bc]	2.15	0.53	<0.01	0.44

[abc]Within a row, least squares means without a common superscript differ ($P \leq 0.05$).

at day 30 while the greatest N losses were for 10% biochar pans harvested at day 30.

Phosphorus losses were not impacted by treatment ($P \geq 0.37$) and averaged 5.98%. There was an effect of day for K ($P < 0.01$) with pans harvested at 30 d having greater K losses compared to pans harvested at 60 d. Biochar inclusion did not impact K losses ($P = 0.53$). The quantities and losses of both P and K were small and there is a challenge in accurately measuring these small quantities.

Results from this study suggest that biochar, included at 5 or 10% of manure DM content, is not a sufficient method to improve nutrient capture from cattle manure. These results are dissimilar to previous literature on the use of biochar inclusion to capture manure nutrients although previous studies focused on manure from animals other than cattle. One primary difference in this study is that manure was collected from covered feedlot pens with slatted floors, thus DM content of the manure was less than 20% and N content was over 5% of DM. Increasing the amount of biochar added may impact the results but could also become expensive, depending on the type and source of biochar.

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Using Coal Char from Sugar Production in Cattle Manure Management

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Summary with Implications

Application of coal char, a coal combustion residue from the sugar factory in Scottsbluff, NE (containing up to 30 % C by weight), was evaluated as a nitrogen (N) loss mitigation tool for feedlot manure in three experiments. In experiment 1, when char was added to piled manure previously removed from feedlot pens, N loss potential was reduced (44% vs. 68% in the control). In experiment 2, manure was collected fresh from the animal, from the pen surface with cattle still in the pen, and from a pile removed from the pen. Char was mixed with these samples in replicated buckets. Total N in manure samples was in order of fresh > pen > pile in the control treatment (no char) on all three sampling events in this 100-day experiment. In char added samples, total N in piled manured was always less than in fresh or pen manure. Total N in fresh and pen manure was similar on 2 occasions out of 3 sampling events. In experiment 3, char (0.625 ton/ head) was applied to the pen surface prior to housing cattle in the pens and compared to pens with no char. Steers were fed a common dry rolled corn-based diet for 218 days. Moisture meters indicated pens with char were drier than pens without. Final body weight, daily gain, dry matter intake, and efficiency were not different due to pen treatment. These data indicate applying char from the sugar beet factory to feedlot pen surfaces may be a N loss mitigation strategy.

Introduction

Coal char is a coal combustion residue (CCR) from a sugar factory in Scottsbluff, NE. Unlike regular CCR from coal-fired power plants, this char contains up to 30 % C by wt. and some plant essential nutrients such as N, P, K, Ca, S, Zn, and Fe. It contains heavy metals (As, Cd, Cr, Pb, Hg, and Se), but their concentrations are below the US EPA's ceiling concentration limits for soil contamination or phytotoxicity in soil. Coal char has a pH of 7.6, surface area of 400 sq ft/ ton, and cation exchange capacity of 47 meq/100g.

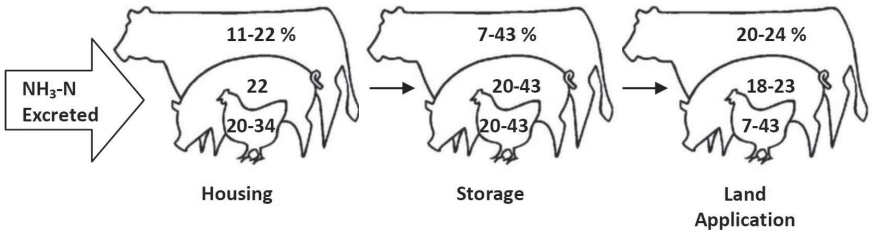

Figure 1. Percent ammonia emissions from total manure-ammonia in each component of livestock operation (EPA National Emissions Estimates, 2005).

In manure management, depending on method and duration of storage, there is a potential risk of significant loss of N which is a valuable crop nutrient (Figure 1). In open cattle feedlot operation, the partitioning of ammonia loss at different stages can be 90/5/5 (housing/storage/land application), which underscores the importance of management intervention at early stages of manure handling for a N loss mitigation strategy. Lignite, when applied on the pen surface, has been demonstrated to reduce ammonia volatilization from cattle feedlot manure by 66 % through its strong acidity (pH 3.69), strong adsorption of ammonium as well as biological immobilization due to high carbon content. Coal char discussed in the paper comes from sub-bituminous coal.

The recommended C:N ratio for feedlot and dairy manure is between 25 and 40:1. At lower C:N ratios, ammonia losses are increased because the energy substrate for microbial growth is limiting. Between 60% and 75% of the N consumed by the animal is lost to volatilization after being excreted until it is applied to fields. Increasing the C:N ratio of feedlot manure has been successful in reducing the amount of N lost from the feedlot. Since coal char contains up to 30% C, it might shift microbial process towards N conservation in manure when mixed in with manure. Additionally, the char might also physically retain N by electrostatic adsorption to its exchange sites. Previous research has shown char at optimal rates reduced ammonia volatilization loss in fertilized soil in a laboratory setting.

Strategies to mitigate ammonia emissions from feedlot operations may involve changing diet formulation, using additives or management to alter soil and storage conditions of manure. However, these strategies are cost-prohibitive in most cases and hence, lack wide adoption. The char from Western Sugar has the potential to be an economic solution in this regard.

The objective of these experiments was to evaluate coal char as a manure amendment to reduce N loss at various stages of manure handling and storage before land application.

Procedure

Experiment 1. Manure from pens was scraped and piled on a cement apron, sampled, weighed, and hauled to the manure storage plot in the spring 2017. Eight piles were constructed with 4 piles receiving char and 4 control piles. Each pile weighed about 2600 lbs. The char and manure mixture pile (CHAR treatment) had 1600 lbs of manure and 1000 lbs of char. The CHAR treatments were mixed using a rototiller. Samples were collected on d 0 during pile construction from the control (CON) and char (CHAR)

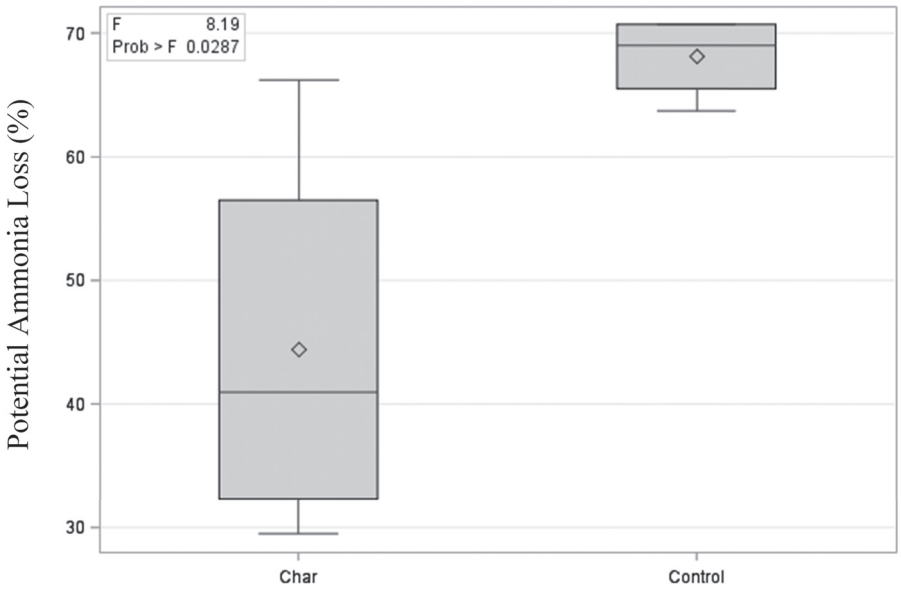

Figure 2. Distribution (and average; diamond) of ammonia loss potential under manure only (CON) and char-treated manure (CHAR) treatments (Experiment 1).

Table 1. Moisture and Potential Ammonia Loss by treatments in the Experiment 1.

Treatment	Rep	Moisture (%)	Ammonium-N (lbs), 24 hr @ 212 F		Potential Ammonia loss (%)
			before	after	
Manure	1	25.61	2.64	0.96	64
Manure	2	27.68	2.73	0.80	71
Manure	3	24.73	3.25	1.06	67
Manure	4	22.56	2.81	0.82	71
Manure+Char	1	23.74	1.30	0.84	35
Manure+Char	2	31.27	2.72	0.92	66
Manure+Char	3	26.45	1.96	1.04	47
Manure+Char	4	25.47	2.11	1.49	30

Treatment included Control (manure only) and Char (manure mixed with char).

treatments. Ammonium-N was measured on samples as-is and after drying for 24 h in a 212° F oven to determine the ammonia volatilization potential. Effect of treatments (CHAR and CON) on N loss potential was evaluated by using Analysis of Variance (ANOVA) test in SAS.

Experiment 2. Manure was collected at three stages; freshly deposited from cattle in pens, manure from the pen surface while cattle were still housed in the pen, and manure scraped out of pens when cattle were removed and piled on ground for storage. Eight 5-gallon buckets were filled with manure collected at each sampling stage with 4 buckets receiving char (treatment CHAR) and 4 manure only (control treatment, CON) buckets. Char was added to manure in 1:1 ratio (dry wt.). A few 2-cm holes were drilled at bottom of buckets to avoid water ponding in the events of rainfall during the experiment and filter paper was spread at bottom of buckets before adding char and manure to avoid any loss of treatment materials. Samples from each bucket were collected using soil probes on d 33, d 66 and d 100. Samples were analyzed for organic N, ammonium N, nitrate N and total N as well as organic carbon and minerals. Effects of treatments on manure N and other nutrients were determined by using Proc Mixed test in SAS where manure stages (fresh, from pens and pile), and char treatment (CHAR and CON) were the main effects.

Experiment 3. The experiment was conducted in a completely randomized design with 5 replications. Treatments were char (0.625 ton/head; CHAR) or no char (0 ton/ac; CON). Char was spread uniformly within the cattle pens prior to cattle being housed in the pens. Soil moisture sensors were installed at 5 in depth in one pen from each treatment. Pens were assigned randomly to treatment. Steers (n=100; initial wt=703±15.6 lb) were stratified by weight and assigned to pen. Prior to trial initiation, steers were limit fed (2% BW) a common diet to reduce gut fill and weight variation for 5 days. Steers were then weighed two consecutive days and the weight average was used as the initial weight for the experiment. Steers were fed a common dry-rolled corn based finishing diet for 218 d. At the end of the feeding period, cattle were weighed on a pen scale and assessed a 4% shrink on live weight. Cattle were then harvested at a commercial abattoir. Sub samples of the manure scraped from the pens were analyzed for nutrient contents.

Results

Experiment 1. Ammonia volatilization potential was significantly lower for CHAR (44%) compared with CON (68%) (P = 0.03) (Figure 2). One replication of the CHAR treatment had 66% ammonia loss potential, close to the average of manure only CON treatment because of its higher moisture content (31%) compared to the rest of the replications (23-26%) (Table 1). The higher the moisture content, the greater the evaporative loss of ammonia.

Experiment 2. Total N in manure samples was in order of fresh > pen > pile in the control treatment (no char) on all 3 sampling events in this 100-day experiment (Figure 2). Compared to fresh manure, piled and pen manure had total N less by around 51 and 34% respectively. In char added samples, total N in piled manured was always less than in fresh or pen manure. Total N in fresh and pen manure was similar on 2 occasions out of 3 sampling events. Compared to fresh manure, piled and pen manure had total N less by around 38 and 10 % respectively in the CHAR

Table 2. Percentage gain in different elemental concentrations in manure samples due to char addition in the Experiment 2.

Manure	ΔCa	ΔMg	ΔNa	ΔFe	ΔCu	ΔB
Fresh	260	129	20	1052	344	475
Pen	119	76	-23	113	325	274
Pile	176	55	-26	232	202	235

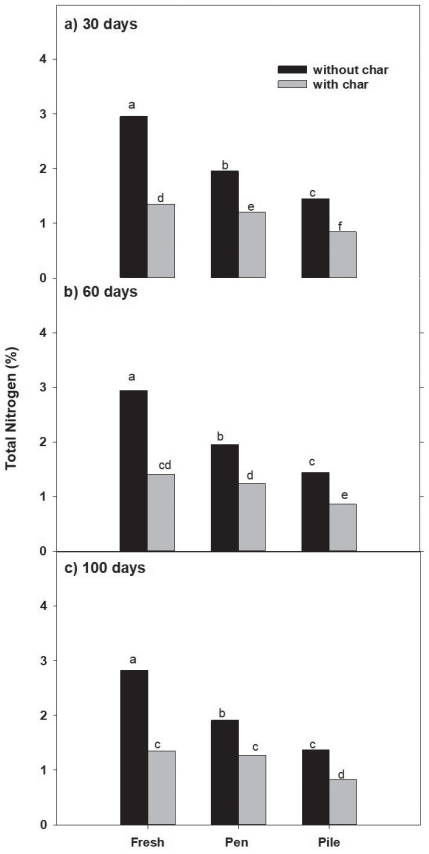

Figure 3. Total N over the period of 100 days after collecting samples from different stages; fresh, pile and pen on a) 30 days, b) 60 days, and c) 100 days. Means with different small letters in each plate are significantly different at $P < 0.05$.

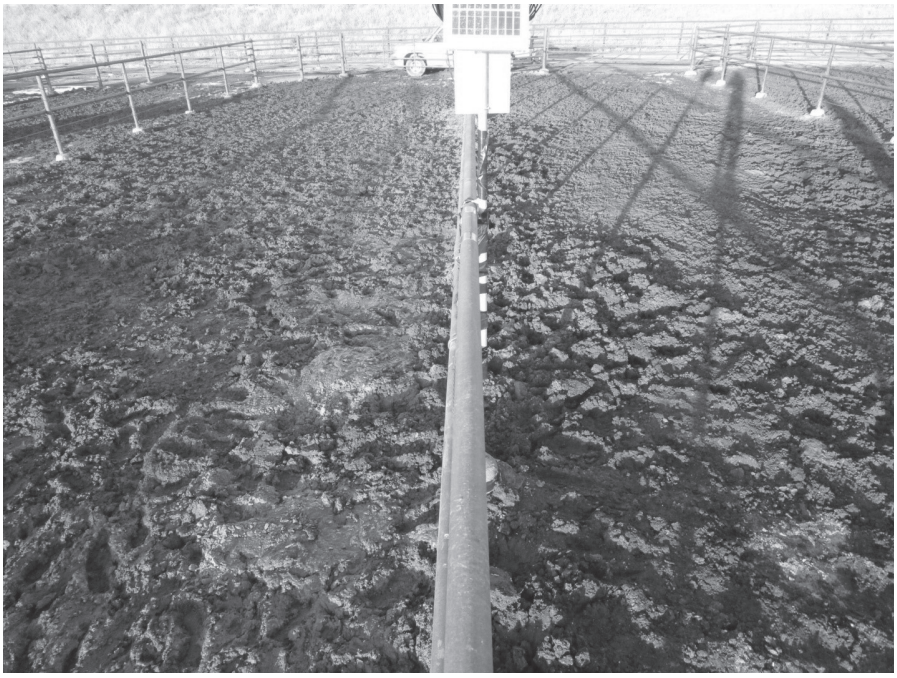

Figure 4. Moisture conditions in the control (left) and the char treatment (right) following Nov. storm.

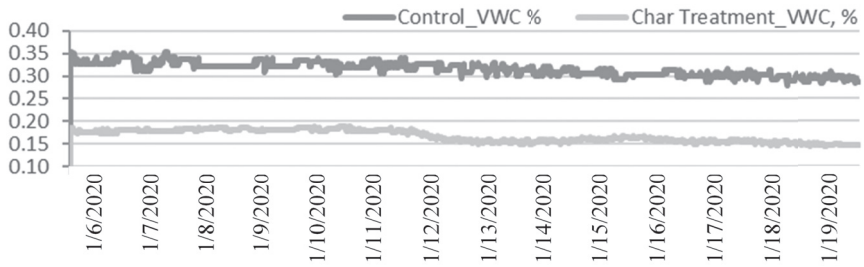

Figure 5. Volumetric water content (VWC) under the no-char and char-applied cattle pens in first half of January 2020.

treatments. It is important to note that total N in the CHAR treatments is not adjusted for added char.

Early the better for management inventions to reduce N loss from manure. However, adding char to fresh manure is not feasible in cattle manure operation. Nitrogen loss portioning in this experiment suggests most of N is lost while collecting in the pen and adding char directly to the pen is a worth an investigation. Adding char to manure samples has another potential benefit of increasing several crop beneficial nutrients such as Ca, Mg, Fe, Cu, and B and decreasing Na (Table 2).

Experiment 3. The pens with CHAR were drier than CON after a series of snowstorms in November (Figures 4). Soil moisture sensor data showed drier pens in CHAR compared with CON (Figure 5). At the end of the experiment, the CHAR treatment was targeted to have a mix of manure and char approximately at 2:1. To achieve that, 12,500 lbs of char was applied to each pen anticipating 25,000 lbs of manure from 10 head. Chemical analysis of the samples collected from the pens with or without char showed decrease in organic, ammonium and total N and P and S in CHAR treatment compared to the control (Table 3).The decrease in those values in the CHAR treatment does not necessarily mean nutrient loss since those values in the CHAR treatment were not adjusted for added char. Moisture levels were significantly lower in the CHAR than in the control treatment. Lower moisture content eases

Table 3. Chemical analysis of manure samples from the pens with or without char application in Experiment 3.

Treatment	Moisture	Organic N	NH4-N	Total N	P	S	Ca	Mg	Zn	Fe	Cu	B	pH
	%								ppm				
CON	31.8a	1.71a	0.03	1.73a	1.66a	0.41a	3.51	0.91	145	8236	41	42	8.1
CHAR	26.0b	1.49b	0.03	1.52b	1.46b	0.36b	3.36	0.86	141	9027	31	40	8.1
P value	<0.0001	<0.0001	0.965	<0.0001	0.025	0.02	0.79	0.63	0.77	0.46	0.43	0.88	0.97

Treatment included Control (manure only) and Char (manure mixed with char).

Means in each column followed by different small cap letters are significantly different at given *P* values.

Table 4. Performance of finishing steers housed in pens with or without char application (Experiment 3).

	CHAR	CONTROL	SE	*P* value
Initial BW, lb	703	703	15.6	0.99
Final BW, lb	1385	1393	20.3	0.79
Daily gain, lb/d	3.98	4.04	0.05	0.51
Dry matter intake, lb/d	25.5	26.0	0.41	0.41
F:G	6.39	6.44		0.72

Treatment included Control (manure only) and Char (manure mixed with char).

the transport and land application of the mix compared to manure only.

There were no significant differences ($P > 0.41$) in initial or final body weight, average daily gain, dry matter intake, or F:G for CHAR vs. CON (Table 4).

Conclusions

Since ammonia from feedlots is a significant source of lost N, reducing emissions from feedlots will achieve local environmental benefits. Data from this study demonstrated a viable use of coal char in manure management, particularly in the pen to reduce nutrient loss and improve manure nutrient contents without impacting cattle performance.

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Transforming Manure and Cedar Mulch from "Waste" to "Worth"

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Summary with Implications

*In nearly every production environment, there are opportunities to capture profits if waste streams can be further processed or enhanced to create "value added" products. Animal feeding operations in Nebraska generate significant amounts of manure that are considered as a "waste" product. Additionally, Eastern red cedar (*Juniperus virginiana*) encroachment into grazing land has become an economic and ecological threat, reducing forage production, fragmenting wildlife habitats, and increasing the risk and severity of wild fires. Value-added uses for cedar woodchips are being sought by the Nebraska Forest Service and other agencies to promote tree management by landowners. Using manure and cedar mulch individually or in combination as soil amendments on agricultural crop land was proposed by farmers in the Middle Niobrara Natural Resource District to assess their impacts on soil health and crop productivity. On-farm research studies were initiated during 2019 at four locations across the state of Nebraska and two more sites were added in 2020. The goal is to document and demonstrate the effects of land applied manure and cedar mulch on agronomic, economic and soil health variables in corn fields under different agro-climatic conditions. Results from the 2019 cropping season indicate that pre-plant applications of beef manure can make significant contributions of nitrogen (N), phosphorus (P) and potassium (K) and K in crop fields without compromising yield, constituting a reliable resource to replace inorganic fertilizers. Depending on initial soil quality, manure also increased soil organic matter (SOM) concentration, pH, and electrical conductivity (EC). Surface applications of cedar mulch did not promote soil acidification or N immobilization, although it induced soil nitrate reduction in top soil layers when incorporated after crop harvest at one research site.*

Introduction

Recycling locally available livestock manure nutrients prior to importing commercial fertilizer is an essential component to improving water quality in areas of intensive livestock production. At the same time, environmental, ecological, economic and social threats posed by eastern red cedar tree proliferation are substantial and relevant throughout much of Nebraska. Individually or together, cedar mulch produced during tree management activities and manure from livestock operations could be beneficial to soil health and crop productivity when applied to agricultural cropland. Following small plot studies at two Nebraska Sandhills farms to measure soil health and crop productivity metrics over three cropping seasons under treatments with manure and mulch, a statewide study was initiated in spring 2019 to expand evaluation of these amendments to large-scale plots in corn fields throughout Nebraska.

Procedure

Research was initiated during spring 2019 on four on-farm research sites located near Saint Paul, Pierce, Ainsworth and Brule, Nebraska. Plots (40 ft. x 350 ft.) were established at these sites prior to the 2019 growing seasons to accommodate at least three different treatments (manure, manure+woody biomass, and control plots that received only inorganic fertilizer) with each treatment replicated four times. Buffers between plots measured 40 ft. Manure sources for these sites included beef feedlot manure at two sites and bedded beef barn manure or beef slurry manure at the other two sites. At the site near Brule, woody biomass was replaced by coal char from a Colorado sugar beet processing plant since wood chips were not readily available. Preplant nitrogen application was the same among all plots within a single site, whether supplied by manure, fertilizer, or a combination of both.

Initial soil chemical, physical and biological properties were determined with soil samples taken before the application of treatments. Subsequent samples were collected at the end of the 2019 cropping season and corn yield was determined for all research sites.

Results

Statistical analysis to assess treatment and experimental effects and interactions between treatments included a one-way or two-way analysis of variance. Least significant difference (LSD) was used to determine differences between treatments at the α=0.05 level. Results indicate that single pre-plant manure applications can make significant contributions of macronutrients (N, P and K), constituting a reliable resource to replace inorganic fertilizers. With N balanced among all treatments within each site, no changes in crop yield were observed with manure applications. Depending on initial soil quality, manure also increased SOM, pH, and EC. Surface applications of woody biomass did result in soil acidification or N immobilization, although it induced soil nitrate reduction in top soil layers when incorporated after crop harvest at one research site. More research is being performed during 2020 and two more research sites, located near Julian and Overton, will be added for a first year of treatments.

Conclusions

While in-season application of beef manure remains incompatible with most

cropping and manure management systems, utilizing beef manure to replace part or all of corn's pre-plant N needs appears feasible without negatively impacting yield. Most soil physical properties change quite slowly and may require multiple years of manure application to improve. This study will continue for at least two additional cropping seasons to allow assessment of long-term impacts on crop productivity and soil quality with additional annual treatment applications.

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Table 1. Average initial soil chemical properties for sites A, B, C and D.

	Depth (cm)	SOM (%)	CEC (me $100g^{-1}$)	pH	EC (mmho cm^{-1})	NO_3^--N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Site A	**0-10**	3.03	14.5	6.15	0.14	11.5	26.5	374.8	7.2	1718.3	193.0	12.5
	10-20	2.05	15.8	6.23	0.12	6.3	9.0	852.8	5.6	2110.5	238.0	16.5
	20-51	-	-	-	-	3.6	-	-	-	-	-	-
	51-91	-	-	-	-	1.85	-	-	-	-	-	-
Site B	**0-10**	2.00	7.4	6.58	0.09	4.0	26.3	234.0	5.7	974.8	122.2	10.4
	10-20	1.33	6.5	6.48	0.07	3.2	29.3	155.6	6.1	896.7	105.9	9.8
	20-51	-	-	-	-	3.1	-	-	-	-	-	-
	51-91	-	-	-	-	2.4	-	-	-	-	-	-
Site C	**0-10**	1.39	5.7	5.98	0.05	1.7	13.8	203.1	3.9	496.1	57.1	7.2
	10-20	0.88	6.3	5.35	0.05	1.6	19.6	124.9	7.0	444.9	48.3	9.9
	20-51	-	-	-	-	2.4	-	-	-	-	-	-
	51-91	-	-	-	-	1.9	-	-	-	-	-	-
Site D	**0-10**	1.56	9.3	7.58	0.14	6.4	23.1	345.8	6.9	1226.1	224.8	92.9
	10-20	1.32	9.0	7.36	0.15	7.0	21.9	261.1	12.5	1250.9	208.8	76.8
	20-51	-	-	-	-	6.5	-	-	-	-	-	-
	51-91	-	-	-	-	4.2	-	-	-	-	-	-

Note: SOM=soil organic matter, CEC=cation exchange capacity, EC=electrical conductivity, NO_3-N=nitrate-nitrogen, P=phosphorous, K=potassium, SO_4-S = sulfate-sulfur, Ca=calcium, Mg=magnesium, Na=sodium.

Table 2. Average soil chemical properties for the 0-20 cm soil layers by treatments, for site A.

	Factor	SOM (%)	pH	CEC (me 100g $^{-1}$)	EC (mmho cm^{-1})	NO_3-N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Treatment	CON	2.21	6.09 $^{a\ b}$	12.28	-	-	-	270.9	8.0	1670.1	178.1 $^{a\ b}$	10.8
	CM	2.00	5.86 ^{b}	11.98	-	-	-	236.8	8.9	1545.5	173.5 ^{b}	10.6
	WB	2.19	5.99 ^{b}	12.83	-	-	-	278.9	7.1	1674.5	189.4 $^{a\ b}$	11.8
	CMWB	2.28	6.24 ^{a}	13.90	-	-	-	333.8	8.3	1950.9	217.4 a	12.3
	0-10	2.64 ^{a}	6.04	12.28	-	-	-	330.1	8.6	1567.3 ^{a}	162.4 ^{a}	9.9 ^{a}
Depth (cm)	CON	-	-	-	0.13	12.5 ^{b}	19.5 ^{b}	-	-	-	-	-
	CM	-	-	-	0.12	17.2 ^{a}	35.3 ^{a}	-	-	-	-	-
	WB	-	-	-	0.11	11.4 ^{b}	40.5 ^{b}	-	-	-	-	-
	CMWB	-	-	-	0.14	12.3 ^{b}	30.8 ^{b}	-	-	-	-	-
	10-20	1.70 ^{b}	6.04	13.21	-	-	-	230.1	7.6	1853.3 ^{b}	216.8 ^{b}	12.8 ^{b}
	CON	-	-	-	0.11	4.5	7.0	-	-	-	-	-
	CM	-	-	-	0.11	7.2	8.3	-	-	-	-	-
	WB	-	-	-	0.13	3.7	10.5	-	-	-	-	-
	CMWB	-	-	-	0.13	5.6	8.0	-	-	-	-	-
	trt	0.4045	0.0335	0.2089	-	-	-	0.1164	0.3714	0.1521	0.0403	0.4363
	depth	0.0122	1.0000	0.2268	-	-	-	0.0551	0.1429	<.0001	<.0001	0.0234
	0-10	-	-	-	0.5929	0.0027	0.0092	-	-	-	-	-
	10-20	-	-	-	0.3740	0.1106	0.9285	-	-	-	-	-
	trt*depth	0.2709	0.1641	0.1108	0.0482	0.0355	0.0155	0.1179	0.1937	0.3729	0.4289	0.1951

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-10 cm soil layer, and "x", "y" and "z" for the 10-20 cm layer. CM= cattle manure; CMWB=cattle manure and woody biomass; CON=control; WB= woody biomass.

Table 3. Average soil physical properties for the 0-20 cm soil layers and corn yield by treatments, for site A.

	Factor	Mean Weight Diameter (mm)	Water-Stable Macroaggregates (%)	Bulk Density (g cm $^{-3}$)	Sorptivity (cm sec$^{-1/2}$)	Corn Yield (Mg ha^{-1})
Treatment	CON	2.82	84.3	1.47	-	11.28
	CM	2.72	84.6	1.46	-	10.29
	WB	2.78	83.6	1.42	-	10.74
	CMWB	2.89	84.3	1.42	-	10.53
	0-10	-	-	1.36 ^{a}	-	-
Depth (cm)	CON	-	-	-	-	-
	CM	-	-	-	-	-
	WB	-	-	-	-	-
	CMWB	-	-	-	-	-
	10-20	-	-	1.52 ^{b}	-	-
	CON	-	-	-	-	-
	CM	-	-	-	-	-
	WB	-	-	-	-	-
	CMWB	-	-	-	-	-
	trt	0.9352	0.9469	0.1838	-	0.7331
	depth	-	-	0.0114	-	-
	0-10	-	-	-	-	-
	10-20	-	-	-	-	-
	trt*depth	-	-	0.6410	-	-

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-5 cm soil layer, and "x", "y" and "z" for the 5-10 cm layer. CM= cattle manure; CMWB=cattle manure and woody biomass; CON=control; WB= woody biomass.

Table 4. Average soil chemical properties for the 0-20 cm soil layers by treatments, for site B.

	Factor	SOM (%)	pH	CEC (me 100g $^{-1}$)	EC (mmho cm^{-1})	NO_3-N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Treatment	CON	1.10	-	-	-	-	37.1	-	9.0	715.8 ^{b}	-	7.1
	CS	1.36	-	-	-	-	47.4	-	10.5	934.9 ^{a}	-	8.1
	CSWB	1.26	-	-	-	-	35.4	-	8.7	864.9 ^{a}	-	7.5
Depth (cm)	**0-10**	1.58 ^{a}	-	-	-	-	43.5	-	8.9	824.3	-	7.7
	CON	-	5.68 ^{b}	7.58	0.14 ^{b}	11.1	-	147.8 ^{b}	-	-	89.0 ^{b}	-
	CS	-	5.98 ^{a}	8.45	0.28 ^{a}	19.6	-	254.8 ^{a}	-	-	122.8 ^{a}	-
	CSWB	-	6.13 ^{a}	8.70	0.17 $^{a\,b}$	18.1	-	223.0 ^{a}	-	-	121.8 ^{a}	-
	10-20	0.90 ^{b}	-	-	-	-	36.4	-	9.9	852.8	-	7.5
	CON	-	6.10	6.63	0.13	7.1	-	129.5 ^{y}	-	-	85.5 ^{y}	-
	CS	-	6.15	7.98	0.13	15.0	-	198.0 ^{x}	-	-	120.3 ^{x}	-
	CSWB	-	6.18	7.35	0.18	8.5	-	154.5 ^{y}	-	-	102.8 ^{xy}	-
	trt	0.0886	-	-	-	-	0.2245	-	0.1068	0.0373	-	0.5457
	depth	0.0162	-	-	-	-	0.3383	-	0.1806	0.3603	-	0.8205
	0-10	-	0.0041	0.2332	0.0293	0.0557	-	0.0007	-	-	0.0102	-
	10-20	-	0.8109	0.1644	0.3272	0.0815	-	0.0150	-	-	0.0171	-
	trt*depth	0.2812	0.0398	0.0509	0.0244	0.0072	0.5363	0.0424	0.1068	0.0677	0.0453	0.1318

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-10 cm soil layer, and "x", "y" and "z" for the 10-20 cm layer. CS= cattle slurry; CSWB=cattle slurry and woody biomass; CON=control.

Table 5. Average soil physical properties for the 0-20 cm soil layers and corn yield by treatments, for site B.

	Factor	Mean Weight Diameter (mm)	Water-Stable Macroaggregates (%)	Bulk Density (g cm $^{-3}$)	Sorptivity (cm sec$^{-1/2}$)	Corn Yield (Mg ha^{-1})
Treatment	CON	2.22	27.0 ^{b}	1.53	0.13	15.56
	CS	2.45	43.6 ^{a}	1.52	0.17	15.13
	CSWB	2.35	45.9 ^{a}	1.52	0.19	14.94
Depth (cm)	**0-10**	-	-	1.46 ^{a}	-	-
	CON	-	-	-	-	-
	CS	-	-	-	-	-
	CSWB	-	-	-	-	-
	10-20	-	-	1.59 ^{b}	-	-
	CON	-	-	-	-	-
	CS	-	-	-	-	-
	CSWB	-	-	-	-	-
	trt	0.9139	0.0540	0.9345	0.1995	0.5622
	depth	-	-	0.0004	-	-
	0-10	-	-	-	-	-
	10-20	-	-	-	-	-
	trt*depth	-	-	0.1068	-	-

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-5 cm soil layer, and "x", "y" and "z" for the 5-10 cm layer. CS= cattle slurry; CSWB=cattle slurry and woody biomass; CON=control.

Table 6. Average soil chemical properties for the 0-20 cm soil layers by treatments, for site C.

	Factor	SOM (%)	pH	CEC (me 100g $^{-1}$)	EC (mmho cm^{-1})	NO_3-N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Treatment	CON	-	-	7.04	-	-	-	121.4 ^{b}	7.0 ^{bc}	-	-	-
	CM	-		7.24	-	-	-	161.8 ^{a}	7.9 ^{ab}	-	-	-
	WB	-		6.53	-	-	-	124.6 ^{b}	6.6 ^{c}	-	-	-
	CMWB	-		7.44	-	-	-	159.6 ^{a}	8.7 ^{a}	-	-	-
	0-10	-	-	6.74 ^{a}	-	-	-	165.3 ^{a}	6.7 ^{a}	-	-	-
	CON	1.58 ^{b}	5.73 ^{c}	-	0.10 ^{b}	7.2 ^{b}	12.8 ^{b}	-	-	678.0	78.5 ^{b}	7.8
	CM	1.83 ^{a}	6.20 ^{a}	-	0.13 ^{a}	11.9 ^{a}	47.3 ^{a}	-	-	749.5	119.3 ^{a}	7.3
	WB	1.60 ^{b}	5.83 ^{bc}	-	0.09 ^{b}	6.5 ^{b}	13.0 ^{b}	-	-	640.3	77.8 ^{b}	7.0
Depth (cm)	CMWB	1.85 ^{a}	6.15 ^{ab}	-	0.13 ^{a}	10.7 ^{a}	56.8 ^{a}	-	-	724.3	116.8 ^{a}	7.5
	10-20	-	-	7.38 ^{b}	-	-	-	118.4 ^{b}	8.4 ^{b}	-	-	-
	CON	0.95	5.28	-	0.07	3.7	14.0	-	-	579.3	63.8	8.8
	CM	0.95	5.15	-	0.08	4.6	24.3	-	-	549.5	67.0	9.5
	WB	1.00	5.23	-	0.07	3.3	18.3	-	-	566.8	68.0	8.3
	CMWB	0.98	5.10	-	0.07	3.9	28.3	-	-	476.5	54.5	9.3
	trt	-	-	0.2935	-	-	-	0.0233	0.0068	-	-	-
	depth	-	-	0.2070	-	-	-	0.0088	0.0060	-	-	-
	0-10	0.0032	0.0253	-	0.0045	0.0004	<.0001	-	-	0.3244	0.0007	0.6500
	10-20	0.9052	0.6958	-	0.4006	0.7919	0.1683	-	-	0.3677	0.5461	0.2307
	trt*depth	0.0098	0.0009	0.3747	0.0541	0.0222	0.0010	0.0591	0.3450	0.0005	0.0004	0.0530

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-10 cm soil layer, and "x", "y" and "z" for the 10-20 cm layer. CM= cattle manure; CMWB=cattle manure and woody biomass; CON=control; WB= woody biomass.

Table 7. Average soil physical properties for the 0-20 cm soil layers and corn yield by treatments, for site C.

	Factor	Mean Weight Diameter (mm)	Water-Stable Macroaggregates (%)	Bulk Density (g cm $^{-3}$)	Sorptivity (cm sec$^{-1/2}$)	Corn Yield (Mg ha^{-1})
Treatment	CON	1.46	26.0	1.54	0.12 ^{c}	14.09
	CM	1.49	27.7	1.47	0.15 ^{bc}	13.83
	WB	1.61	25.4	1.51	0.19 ^{ab}	13.09
	CMWB	1.52	29.5	1.50	0.21 ^{a}	13.91
	0-10	-	-	1.40 ^{a}	-	-
	CON	-	-	-	-	-
	CM	-	-	-	-	-
	WB	-	-	-	-	-
Depth (cm)	CMWB	-	-	-	-	-
	10-20	-	-	1.61 ^{b}	-	-
	CON	-	-	-	-	-
	CM	-	-	-	-	-
	WB	-	-	-	-	-
	CMWB	-	-	-	-	-
	trt	0.9847	0.9052	0.2555	0.0190	0.3362
	depth	-	-	0.0004	-	-
	0-5	-	-	-	-	-
	5-10	-	-	-	-	-
	trt*depth	-	-	0.2485	-	-

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-5 cm soil layer, and "x", "y" and "z" for the 5-10 cm layer. CM= cattle manure; CMWB=cattle manure and woody biomass; CON=control; WB= woody biomass.

Table 8. Average soil chemical properties for the 0-20 cm soil layers by treatments, for site D.

	Factor	SOM (%)	pH	CEC (me 100g $^{-1}$)	EC (mmho cm^{-1})	NO_3-N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Treatment	CON	-	-	-	-	-	-	383.1	-	-	-	-
	CM	-	-	-	-	-	-	494.9	-	-	-	-
	CC	-	-	-	-	-	-	384.6	-	-	-	-
	CMCC	-	-	-	-	-	-	453.1	-	-	-	-
Depth (cm)	**0-10**	-	-	-	-	-	-	472.3 ^{a}	-	-	-	-
	CON	1.40 ^{b}	7.65 ^{bc}	9.40	0.25	6.1 ^{b}	27.0 ^{b}	-	23.2 ^{c}	1262.8	216.0	53.5
	CM	1.78 ^{a}	7.48 ^{c}	10.58	0.28	19.5 ^{a}	158.8 ^{a}	-	40.8 ^{bc}	1317.5	269.8	70.3
	CC	1.65 ^{a}	7.83 ^{ab}	10.80	0.24	10.3 ^{b}	50.8 ^{b}	-	59.3 ^{ab}	1487.3	244.3	59.8
	CMCC	1.85 ^{a}	7.85 ^{a}	11.73	0.27	18.6 ^{a}	158.5 ^{a}	-	77.5 ^{a}	1554.8	283.5	61.0
	10-20	-	-	-	-	-	-	385.6 ^{b}	-	-	-	-
	CON	1.00	7.33 ^{xy}	8.75	0.22	4.6	17.5	-	45.4	1174.5	201.0	63.8
	CM	1.08	7.20 ^{y}	10.20	0.36	10.7	24.5	-	48.0	1349.3	237.8	85.8
	CC	0.93	7.15 ^{y}	8.55	0.29	4.3	20.75	-	45.1	1133.5	201.5	63.3
	CMCC	1.00	7.40 ^{x}	8.60	0.27	8.1	31.5	-	54.3	1116.0	201.0	66.8
	trt	-	-	-	-	-	-	0.1287	-	-	-	-
	depth	-	-	-	-	-	-	0.0201	-	-	-	-
	0-10	0.0082	0.0018	0.2042	0.0563	<.0001	<.0001	-	0.0004	0.1165	0.1062	0.5098
	10-20	0.6348	0.0442	0.3372	0.7836	0.1075	0.9435	-	0.7918	0.2777	0.4341	0.1812
	trt*depth	0.0015	0.0436	0.0024	0.0525	0.0263	0.0094	0.1818	0.0136	0.0009	0.0080	0.0415

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-10 cm soil layer, and "x", "y" and "z" for the 10-20 cm layer. CM= cattle manure; CMCC=cattle manure and coal char; CON=control; CC= coal char.

Table 9. Average soil physical properties for the 0-10 cm soil layers and corn yield by treatments, for site D.

	Factor	Mean Weight Diameter (mm)	Water-Stable Macroaggregates (%)	Bulk Density (g cm $^{-3}$)	Sorptivity (cm sec$^{-1/2}$)	Corn Yield (Mg ha^{-1})
Treatment	CON	0.58	19.42	-	0.09	12.50 ^{a}
	CM	0.85	24.98	-	0.10	13.52 ^{a}
	CC	0.70	22.19	-	0.09	10.43 ^{b}
	CMCC	0.52	19.14	-	0.09	13.10 ^{a}
Depth (cm)	**0-5**	-	-	-	-	-
	CON	-	-	1.66 ^{c}	-	-
	CM	-	-	1.61 ^{bc}	-	-
	CC	-	-	1.54 ^{ab}	-	-
	CMCC	-	-	1.50 ^{a}	-	-
	5-10	-	-	-	-	-
	CON	-	-	1.79	-	-
	CM	-	-	1.78	-	-
	CC	-	-	1.80	-	-
	CMCC	-	-	1.84	-	-
	trt	0.2038	0.4013	-	0.9157	0.0311
	depth	-	-	-	-	-
	0-5	-	-	0.0020	-	-
	5-10	-	-	0.4574	-	-
	trt*depth	-	-	0.0003	-	-

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-5 cm soil layer, and "x", "y" and "z" for the 5-10 cm layer. CM= cattle manure; CMCC=cattle manure and coal char; CON=control; CC= coal char.

Predicting Nitrogen and Phosphorous Flows in Beef Open Lots

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Richard K Koelsch

Summary with Implications

Manure collected from open lot animal housing systems experiences variability due to weather conditions, management of beef cattle and pens, and other factors resulting in substantial changes in manure characteristics. Data from 15 winter and summer periods at the beef feedlot at Eastern Nebraska Research and Extension Center including 416 independent pen measurements, were summarized for nutrient mass balance, and then used to determine sources of variability impacting nitrogen and phosphorous. Understanding variability is important to regulated manure nutrient planning processes. The results of this review suggest significant challenge associated with planning based upon standard values for estimating manure characteristics. Nutrient planning estimates based upon site and time specific manure analysis is critical for open lot beef systems.

Introduction

Federal and state regulations set environmental standards for beef open lot systems. The U.S. Environmental Protection Agency requires larger open lot systems to be permitted under the National Pollutant Discharge Elimination System (NPDES) process to ensure control of precipitation driven runoff and utilization of manure nutrients in cropping systems. Planning procedures rely upon standard values published by USDA Natural Resource Conservation Service (NRCS) and American Society of Agricultural and Biological Engineers (ASABE) for open lot beef cattle manure quantities and characteristics.

Defining the characteristics of manure and runoff from open earthen lots experiences unique challenges compared with confined animals under roof including variables such as:

- Climatic conditions impacts,
- Pen manager's challenge for distinguishing between compacted soil and manure,
- Animal and manure management practice (e.g. frequency of manure collection),
- Diets fed due to ability of ruminant animals to utilize a variety of by-products, forages and crop residues.

Table 1. Animal performance data collected from 216 and 200 pens for summer and winter, respectively, for cattle fed in open feedlot[1].

Item	Summer	Winter	SEM	*P*-value	ASABE[3]
Days on feed	131	171	1.9	< 0.01	153
Initial BW, lb	800	703	16.0	< 0.01	745
Final BW, lb[3]	1295	1303	14.3	0.643	1220
DMI, lb/d	25.0	22.3	0.45	< 0.01	19.7
ADG, lb/d	3.77	3.49	0.035	0.05	3.13
F:G lb/lb	0.158	0.157	0.001	0.490	0.16
Crude protein diet, %	14.7	16.1	0.26	<0.01	13.4
Phosphorus in diet, %	0.33	0.31	0.006	0.067	0.31
Total Precipitation (in)	13.9	9.0	0.35	<0.01	

[1]SUMMER = cattle fed from April to October, WINTER = cattle fed from November to May

[2]Calculated from hot carcass weight, adjusted to 63% common dress.

[3]ASABE: American Society of Agricultural Engineers Standard D384.2, Manure Production and Characteristics.

Procedure

This paper summarizes an existing database collected from cattle finishing trials conducted at Eastern Nebraska Research and Extension Center (ENREC) facility. Over a 15-year period, 416 unique pen observations were evaluated for the impacts of a broad range of weather conditions, dietary treatments, feedlot management practices and nitrogen and phosphorous conservation practices led by Drs. Galen Erickson and Terry Klopfenstein (Table 1). Historically, the data has primarily added to knowledge of dietary impact on animal performance. A pooled analysis of manure and nutrient characteristics from the pen data was performed.

Trial methods followed common procedures for estimating animal performance, nutrient intake and excretion, as-removed manure, and runoff quantities. Losses of nitrogen (N) and phosphorus (P) were estimated using a mass balance comparison of nutrient inputs and known outputs with the difference representing losses or unaccounted P (P remaining in the lot after cleaning).

Standard methods were followed for harvesting manure and determining mass. Representative samples collected for manure and runoff characteristics were frozen at -4°C until analysis. When rainfall occurred, runoff was collected, sampled, and quantified. Standard methods were followed for all manure solids and nutrient analysis following official methods of Association of Official Agricultural Chemists International. The mass data of these trials was assembled in an excel file where analysis was initially completed followed by linear regression SAS to define important correlations.

Table 2. Nitrogen, phosphorus, and dry matter characteristics associated with 216 pens during the summer and 200 pens during the winter for cattle fed in open feedlot pens.[1]

N Characteristics	Summer	Winter	SEM	P-value	ASABE[8]
N intake, lb/head/d	0.54 a	0.50	0.006	<0.01	0.42
N retain, lb/head/d[2]	0.068 a	0.066			0.063
N excreted, lb/head/d[3]	0.48	0.43			0.36
N runoff, lb/head/d[4]	0.014	0.008	0.0009	<0.01	
N manure, lb/head/d	0.11	0.20	0.004	<0.01	0.20
N loss, lb/head/d[5]	0.35	0.22	0.006	<0.01	
N manure, %	1.31	1.19			1.8
N loss, %[6]	73%	52%			
P Characteristics	**Summer**	**Winter**	**SEM**	**P-value**	**ASABE[8]**
P intake, lb/head/d	0.083	0.071	0.0022	<0.01	0.062
P excreted, lb/head/d[3]	0.067	0.056			0.049
P retain, lb/head/d	0.016	0.015			0.013
P runoff, lb/head/d[4]	0.0050	0.0023	0.00040	<0.01	
P manure, lb/head/d[7]	0.039	0.067	0.0023	<0.01	0.082
P manure, %	0.37	0.38	0.01	0.32	0.74
Unaccounted	0.023	-0.014			
DM Characteristics	**Summer**	**Winter**	**SEM**	**P-value**	**ASABE[8]**
As-is, lb/head/d	20.5	28.9	1.83	<0.01	16.5
DM, lb/head/d	11.9[9]	17.6[9]	1.56	<0.01	11.0
OM, lb/head/d	2.2[9]	4.1[9]	0.11	<0.01	3.3
Ash, lb/head/d	9.2[9]	13.4[9]	0.66	<0.01	7.7

[1] Summer = cattle fed from April to October, Winter = cattle fed from November to May.

[2] Calculated using NRC (1996) net protein and net energy equations.

[3] Calculated as N or P intake minus N or P retention.

[4] Number of retention ponds from which data were collected were n=84 in each feeding period for N and n=72 for P

[5] Calculated as N intake minus N retained minus N manure minus N runoff.

[6] Calculated as N lost divided by N excretion.

[7] Number of pens from which data were collected were 132 and 124 in the SUMMER and WINTER, respectively.

[8] ASABE: American Society of Agricultural Engineers Standard D384.2, Manure Production and Characteristics.

[9] Typically, ash plus OM should equal DM. However, data base did not include ash and OM for some pen trials. Thus, reported averages for ash and OM did not precisely match the reported averages for DM.

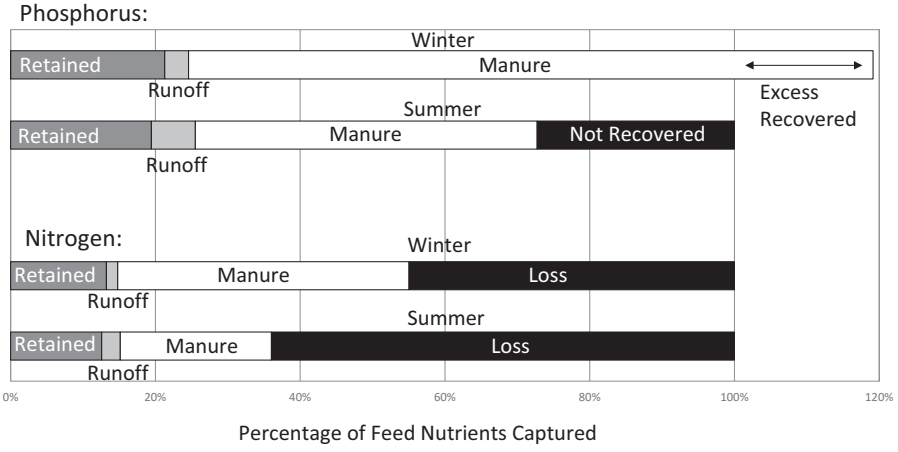

Figure 1. End points for dietary nitrogen and phosphorus consumed by beef for summer and winter-feeding periods.

Results

Nitrogen Balance

Nitrogen entering a feedlot pen as feed will exit the pen in the marketed animal (retained), runoff holding pond water, as-removed manure, and N loss occurring predominantly as ammonia volatilization (Table 2; Figure 1). The evaluation of the independent pen measurements at ENREC suggests that N retained by the marketed animal (approximately 13% of N in feed) are consistent between winter and summer-feeding periods. Nitrogen retained in the manure, runoff and lost is significantly different for winter and summer periods. Nitrogen loss ranged from 65% to 44% of fed N for summer and winter, respectively. As a result of changes in loss during these feeding periods, the manure retains 0.11 and 0.20 lb/head/day for summer and winter periods, respectively, of the 0.54 and 0.50 lb/head/day of nitrogen intake as feed. Feeding period season (summer vs. winter) is an important factor influencing N recovered from open lot systems.

Feed nitrogen intake provides some explanation for observed variability of as-removed manure N and N loss (Table 3) for manure harvested following a summer feeding period, less explanation for the winter feeding period. The data set suggests that an increase of dietary intake of 1 lb results in approximately a 0.30 lb increase in as-removed manure N during the summer (no relationship during the winter). This review suggests that an increase of dietary intake of 1 lb is responsible for a 0.61 lb and 0.84 lb increase in N loss for summer and winter-feeding periods, respectively. A better correlation was observed between N intake and N lost for the summer months [R2 = 0.54 (P<0.01)] and for the winter-feeding period [R2 = 0.37 (P <0.01)].

This review of the correlation between organic matter and N in the manure (Table 3) suggests a strong relationship (R^2 = 0.85 for summer and 0.70 for winter, P < 0.01 for both). Increasing manure's organic matter also appears to reduce N losses. Management practices that increase manure organic matter will impact planning for as-removed manure N and may moderately reduce N emissions.

Table 3. Summary of the ability of some independent variables (X) such as feed intake N to predict dependent variables (Y) such as N in manure for summer and winter-feeding periods (expressed as grams per head per day on feed).

X	Y	Season	Equation	Adj. R^2	P Value
Feed Intake Factors Potentially Impacting N in Manure and N Lost					
Nintake	Nmanure	Summer	Nmanure = 0.29 (+/-0.037) * Nintake - 21 (+/-9.4)	0.22	< 0.01
Nintake	Nmanure	Winter	NO RELATIONSHIP	N/A	N/A
Nintake	Nlost	Summer	Nlost = 0.61 (+/-0.038) * Nintake + 5.9 (+/-9.6)	0.54	<0.01
Nintake	Nlost	Winter	Nlost = 0.84 (+/-0.077) * Nintake – 93 (+/-18)	0.37	<0.01
Feed Intake Factors Potentially Impacting P in Manure					
Pintake	Pmanure	Summer	Pmanure = 0.34 (+/-0.073) * Pintake + 5.0 (+/-2.9)	0.13	< 0.01
Pintake	Pmanure	Winter	Pmanure = 0.46 (+/-0.12) * Pintake + 11.2 (+/-4.0)	0.12	< 0.01
Organic Matter in Manure Potential Impact on N in Manure and N Lost					
OMmanure	Nmanure	Summer	Nman = 0.045 (+/-0.0013) * OMman + 8.0 (+/-1.5)	0.85	< 0.01
OMmanure	Nmanure	Winter	Nman = 0.033 (+/-0.00152) * OMman + 29 (+/-3.1)	0.70	< 0.01
OMmanure	Nlost	Summer	Nlost = -0.014 (+/-0.0046) * OMman + 170 (+/-5.3)	0.040	< 0.01
OMmanure	Nlost	Winter	Nlost = -0.024 (+/-0.0042) * OMman + 140 (+/-8.4)	0.14	< 0.01

Phosphorus Balance

Phosphorus entering a feedlot pen as feed will exit the pen in the marketed animal (retained), runoff holding pond water, or manure (Table 2; Figure 1). Again, the fraction of P retained by the animal remained relatively constant for summer vs winter periods. The as-removed manure P was substantially greater in the winter than summer, exceeding the winter estimate of excreted P. The manure P for summer and winter represented 47% and 95% of fed P, respectively. The runoff P during the summer was double that observed during the winter-feeding period (6 vs 3% of fed P).

These results suggest that a P balance based upon these four inputs and outputs left some P unaccounted, approximately 10 g/head/day in the summer (likely left on the lot surface or mixed in the soil) and -6 g/head/day in the winter. Pen cleaning practice in fall following a summer-feeding period (lot surfaces are drier and soil/manure interface is more easily maintained) resulted in some excreted P not being removed from the pens. Spring pen cleaning following winter feed period more likely involves muddy conditions (and less easily defined soil/manure interface) with more soil and additional P being removed beyond what is excreted. Differences in ash content appear to support this conclusion. These findings suggest that pen cleaning following winter-feeding period was removing P left behind during the cleaning at the end of summer.

Efforts to explain variability in manure P recovery based upon feed P intake demonstrated weak correlations (Table 3). However, planning procedures for managing manure P should recognize the significant differences between winter and summer-feeding periods for as-removed manure P.

Manure Solids

Significant seasonal and individual feeding period variability in the amount of manure harvested was also observed (seasonal variability illustrated in Table 2). Variability in the amount of as-removed manure quantity occurs even when following pre-defined protocols for managing pen surfaces as used at the ENREC feedlot. Total manure, total solids, total organic matter, and total ash were all significantly greater for the winter versus summer-feeding period when expressed on a unit mass per head per day basis. For example, cleaning following winter-feeding period is removing 47% more ash (most likely soil), 87% more organic matter, and 56% more total manure.

These observations of manure solids characteristics variation with winter and summer-feeding period (and similar previous observations for N and P) suggest the need for characterizing and managing manure independently based upon feeding period. Differences at the ENREC feedlot, are due, in part to a summer-feeding period which included higher N and P feed intake, shorter feeding period, and larger animals entering the lot. Differences in weather conditions and pen surface conditions during the time the cattle were in the pens are likely important contributors to variability, commonly impacting the amount of soil (ash content in Table 2) contamination that occurs.

Comparison with Standard Values

As animal performance, feeding program options, and other management practices evolve, standard methods for predicting feedlot manure characteristics and quantities are prone to greater errors. When ASABE assumptions and estimates are compared with field measures in this study, the following observations were made:

- Greater total feed intake, higher average daily gains, and greater finishing weights were observed for the animals finished at the ENREC feedlot, better reflecting industry trends, than the assumed values in the ASABE standard (originally published in 2004).
- ASABE underestimates the dietary N intake and excreted N observed for the ENREC feedlot. Our observed P dietary intake and excretion was also greater than estimated by ASABE.
- ASABE substantially underestimate total manure, dry matter, organic matter, and ash for winter feeding periods. For example, total as-

removed manure averages for both winter, 28.9 lb/head/day, and summer feeding periods, 20.5 lb/head/day, were greater than that of ASABE standards at 16.5 lb/head/day. The ENREC data set also suggests a greater level of ash in the manure than anticipated by ASABE.

- As-removed manure N following winter feeding period for the ENREC feedlot was similar to the ASABE estimate but substantially less following the summer-feeding period. Manure P levels were substantially less than reported by ASABE (more than 50% less in the summer-feeding period). Reduced summer feeding period manure P may be due, in part to P left behind by manure removal in summer followed by its removal the following winter feeding period.

Summary

Standard values for estimating excreted and as-removed manure have historically been used for many planning and design procedures including development of nutrient management plans (often completed years in advance of manure application). These standard values have little to no validity in earthen open-lot animal housing based upon these observations for ENREC feedlot.

In commercial yards that harvest manure following each feeding period (or possibly more often), separately monitoring and managing manure for unique feeding periods is important. Nutrient planning processes should be based on manure sampling protocols that establish a history of feedlot specific manure characteristics, including separate histories for manure removed following winter and summer-feeding periods. Due to the high degree of variability in manure characteristics for individual years and seasons, individual year adjustments for manure and fertilizer rates are essential and should be based upon a just in time manure sample analysis.

Ammonia volatilization from open lots is substantial. For every 1,000 head finished at the ENREC feedlot, the nitrogen loss is approximately 21,000 and 17,000 kg of N for the summer and winter-feeding periods, respectively. This loss is an environmental risks and represents an annual economic loss of roughly $35,000 per 1,000 head for the ENREC feedlot. Experience would suggest that by doubling organic matter in the manure, one might expect to retain approximately two-thirds more nitrogen in the manure.

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Perceptions of Barriers and Benefits of Manure Use in Cropping Systems

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Summary of Implications

Animal agriculture is tasked with recycling the nitrogen and phosphorus in manures in an environmentally sound manner, typically as a soil fertility amendment, which often requires voluntary transfer of manures to crop farms on which there may be little or no history of manure use. The ability of manure to compete with commercially available fertilizers is essential for this transfer. A survey was conducted of farmers' and their advisors' perceptions of the benefits and barriers to manure use in crops. There exists a strong recognition of manure's agronomic, yield, and soil health benefits. However, many challenges associated with manure frequently become barriers to manure use. The survey identified four challenges most likely to prevent manure recycling, including: 1) transportation costs, 2) odor, 3) logistical barriers (e.g. labor availability), and 4) some agronomic questions that will need to be addressed to encourage an expanded role of manure in more cropland.

Introduction

Manure nutrient recycling is critical to the sustainability of the agricultural sector. Many environmental organizations, businesses, and governmental organizations champion the benefits of a "circular economy" for improving sustainability. Agriculture can potentially recycle critical nutrients from animal feed to animal proteins to manure to soils and back to animal feed, applying the idea of a circular economy to manage nitrogen (N) and phosphorus (P). Agriculture's circular economy requires establishing recycling loops for manure nutrients transferred to independent crop farms. Whether recycling of nutrients is completed within a single farm or involves multiple separate agricultural enterprises, this circular agricultural economy for nutrients is essential. More information about agriculture's circular economy may be found at https://go.unl.edu/agcircle

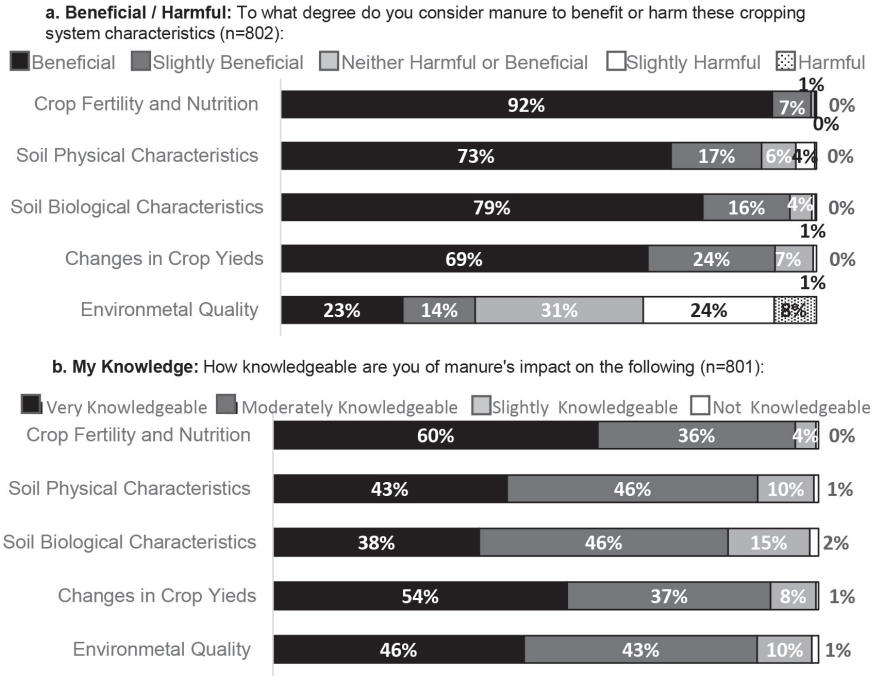

Figure 1. Perceptions and level of knowledge about factors commonly believed to offer benefits to crops or soils.

Procedures

A faculty team from University of Nebraska, University of Minnesota, and Iowa State University is collaborating to deliver Extension programming focused on the "Value of Manure". The team partnered with a stakeholder advisory group to implement a survey conducted in early 2020 to quantify ***perceptions of the benefits and barriers to manure use in cropping systems among farmers and their advisors***. The survey was promoted by The Fertilizer Institute, American Agronomy Society's Certified Crop Advisor program, Manure Manager magazine, and additional partners within our three states.

Results

Completed surveys were received from 957 respondents nationwide. Th results more heavily represent the Corn Belt and High Plains regions, professionals advising on retail agronomy products and services and technical services, and individuals with a history of manure use in their crop fertility program management or advising. Voluntary participation likely resulted in some bias in the survey. A more detailed description of those responding are found at https://go.unl.edu/manurevaluesurvey .

Benefits of Manure Use

Questions asked of survey participants relative to manure benefits targeted:

Table 1. The following is a list of Top Ten challenges to using manure in cropping systems and the regularity of these challenges being identified as a frequent barrier (either real or perceived) preventing manure use.

Top Ten Challenges		Response Count	% of Responses
Economic	Transportation and application costs	693	90%
Neighbor	Odors	597	78%
Logistical	Timeliness of application	555	72%
Logistical	Field conditions limiting application	508	66%
Logistical	Time/labor requirements	486	63%
Agronomic	Application equipment compaction	435	57%
Agronomic	Poor uniformity of application	391	51%
Regulatory	Regulations	381	50%
Agronomic	Weed seed from manure	366	48%
Economic	Initial costs for adding manure	355	46%

Not shown here are 23 additional challenges that were available to be selected. A more detailed listing of challenges and frequency of responses is found at https://go.unl.edu/manurevaluesurvey .

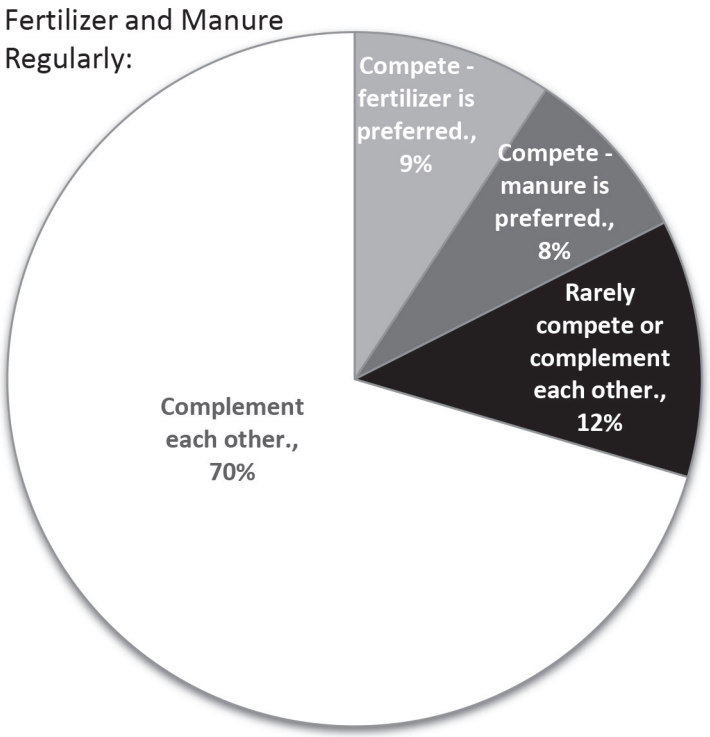

Figure 2. Survey participants responses to what they personally believe is most true in their management decisions (or recommendations) with respect to use of manure and fertilizer in cropping programs?

- Degree participant considers manure to benefit or harm five cropping system characteristic including a) crop fertility and nutrition, b) soil physical characteristics, c) soil biological characteristics, d) changes in crop yield, and e) environmental quality (e.g. erosion, runoff, and nutrient loss to water);
- Level of knowledge of participant for manure's impact on each cropping system characteristic.

Manure was rated as "beneficial" for crop fertility and nutrition by 92% of respondents (Figure 1a). Most surveyed largely agreed that it is beneficial to soil physical (73%) and biological (79%) properties and crop yield (69%), as well. A much smaller portion (37%) agreed that manure is at least slightly beneficial to environmental quality, described in our survey primarily as manure impact on water quality. Thirty two percent perceived manure as at least slightly harmful and 31% indicated it is neither harmful nor beneficial (Figure 1a).

These perceptions of manure as a valued product by those participating in the survey provides a peer group within agriculture which may be influential for promoting the recycling of manure into fields with little or no manure history. However, it is possible that farmers and their advisors may not have the understanding about manure's potential soil and water quality benefits when applied at agronomic rates. Thus, the negative perception of manure's water quality risks continues to persist in rural communities, impeding its expanded recycling in cropland.

Respondents identified as very to moderately knowledgeable (85% to 96%) about the same five Potential Benefits listed in Figure 1b. Somewhat surprising is that a similar level of knowledge was exhibited towards the environmental quality topic as other potential benefits, possibly an awareness of the environmental risks but possibly not the environmental benefits of manure. For the remaining four Potential Benefits evaluated, those surveyed indicate a positive impression and high level of knowledge of those benefits.

Barriers to Manure Use

Conversations with the stakeholder advisory group revealed many potential challenges to manure use in cropping systems, which was assembled into five broad categories: 1) agronomic, 2) economic, 3) community, 4) regulatory, and 5) logistical challenges. A critical purpose of the survey was to identify those challenges that are commonly identified as preventing manure use on some fields. A review of the top ten barriers to manure use in crop fields (Table 1) revealed concerns within all five of the broad categories, suggesting that an array of challenges may ultimately prevent manure's use.

Highest among these risks was an *economic challenge* related to the transportation and application costs of manure (90%

of responses). Just outside the top ten list was the initial cost of adding manure to the fertility program (46%), likely associated with equipment investments. Overcoming economic questions will be critical to expanded manure use.

Neighbor and rural community concerns with odor was the second most common challenge (78%). while water quality impairment and increased traffic, and active opposition to livestock agriculture, were each identified by more than 40% of respondents. Minimizing odor impacts and possibly other rural community concerns need to be addressed for successful manure transfers.

Logistical challenges identified included timeliness of application (72%), field conditions limiting application (66%), and time/labor requirements (63%). *Agronomic challenges* included soil compaction (57%) and poor application uniformity (51%). The challenge of manure for delivering fertility at the right rate and right time compared with conventional fertilizer appears to be a significant impediment to manure use on a broader scope.

The only *regulatory challenge* within the "top ten barriers" list was regulation of manure application practices (50%), such as setbacks. Other commonly identified regulatory challenges included cost of compliance (43%) and local zoning restrictions for odor (41%) were just outside the top ten challenges.

Finally, survey participants were asked to identify which of the following statements were most true in their management decisions (or recommendations) with respect to use of manure and fertilizer (see Figure 2):

- Fertilizer and manure regularly compete with fertilizer typically being preferred (9% selected);
- Fertilizer and manure regularly compete with manure typically being preferred (8% selected);
- Fertilizer and manure are typically used independently and rarely are in competitive or complementary roles (12% selected); or
- Fertilizer and manure regularly complement each other in crop fertility programs (70% selected).

The complementary roles of fertilizer and manure have been documented by two meta-analysis studies as providing the largest average yield increases (averaging from 13% to 18% across all reporting studies). Recognition of the value of co-applying manure and fertilizer and the resulting potential yield benefits could be a powerful argument for expanding manure use in cropland with no previous history.

Summary of Observations

- A strong recognition of manure's fertility, yield, and soil health benefits currently exists among those farmers and advisors who have some history of manure use.
- Manure's water quality benefits are not broadly accepted. This potential benefit of manure, if applied at agronomic rates, may be over-shadowed by negative water quality perceptions from historical over-application of manure.
- The perceived imbalance of manure's benefits against the rather long list of potential risks is a likely reason why many fields are not receiving animal manures. Management strategies and technologies, technical services and education are needed to overcome critical barriers including:
  - Economic questions (economic benefits versus costs for transfer of manure to distant fields);
  - Odor impacts and possibly other rural community concerns;
  - Logistical and agronomic challenges associated with the delivery of manure fertility at the right rate and time within the limited available windows of opportunity; and
  - Additional regulatory oversight of manure versus fertilizer (perceived and real).
- Respondents largely perceive manure and fertilizer as complementary components of a crop fertility program. Recognition of the value of co-applying manure and fertilizer and the resulting potential yield benefits could be a powerful argument for expanding manure use in cropland with no previous history.

A more complete summary of the survey results can be found at https://go.unl.edu/manurevaluesurvey .

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Dietary Impact on Antibiotic Resistance in Feedlot Manure

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Summary with Implications

There is a growing public concern regarding antibiotic resistance and the use of antibiotics, including in livestock management. Understanding the ecology of antibiotic resistance among microbes, identifying resistance gene reservoirs, and implementing antibiotic resistance mitigation practices in livestock production are critical to protecting animal and human health while meeting increasing food demands. This research is one of several studies seeking to assess risk for livestock-to-human transfer of antibiotic resistance and to identify mechanisms for reducing that risk where possible. This study evaluated the impact of forage concentration and supplemental essential oil in beef cattle finishing diets on antibiotic resistance in freshly excreted and consolidated beef feedlot manure. Results indicate that antibiotic resistance in manure was not impacted by either of the two dietary treatments considered.

Introduction

Antibiotics are widely used in agricultural livestock production and human medicine for the treatment of infectious diseases. However, the use of antibiotics applies selective pressure to the gut microbiome of animals and humans, resulting in excretion of antibiotic resistant (AR) bacteria in animal and human feces. The wide spread use of animal manures as fertilizers in agricultural production has resulted in growing concerns about the potential risks of antibiotics, AR bacteria and AR genes present in animal manures and their impact on public, animal, and environmental health.

Forage is included in feedlot diets to improve microbial protein synthesis in the gut but inclusion is minimized because the economic gains from improved ruminal health do not generally outweigh the losses due to a lower average daily weight gain. However, the documented benefits of forage on the ruminal microbiome suggest that increasing forage in finishing diets could reduce AR development in the animals, thereby influencing potential AR-related food safety and environmental exposure risks to people. Essential oils are believed to possess strong antimicrobial effects, suggesting that the addition of essential oils to animal feed may be a viable alternative to antibiotics in animal feed and a means to prevent the development AR in the animal gut.

The objectives of this study were to quantify the effect of essential oil and forage concentration in beef finishing diets on the concentrations of four AR bacterial populations important to human and animal health—azithromycin (AZ)- and tetracy-

Table 1. Effect of essential oil and silage concentration on proportion of *E.coli* resistant to azithromycin or tetracycline in freshly excreted manure and pen surface material

	Fresh Manure		Pen Surface Material	
Variable	AZ^R *E. coli*/ Total *E. coli*	TET^R *E. coli*/ Total *E. coli*	AZ^R *E. coli*/ Total *E. coli*	TET^R *E. coli*/ Total *E. coli*
Essential Oil	P = 0.087	P = 0.148	P = 0.579	P = 0.723
Yes	0.68	0.25	0.74	0.21
No	0.72	0.20	0.75	0.19
Forage Conc.	P = 0.459	P = 0.003	P = 0.743	P = 0.041
80%	0.72	0.21 [b]	0.76	0.15 [a]
47%	0.69	0.18 [a]	0.74	0.25 [b]
14%	0.69	0.17 [a]	0.73	0.19 [ab]

Table 2. Effect of essential oil and silage concentration on proportion of *Enterococci* resistant to tetracycline or tylosin in fresh manure and pen surface material

	Fresh Manure		Pen Surface Material	
Variable	TET^R *Enterococci*/ Total *Enterococci*	TY^R *Enterococci*/ Total *Enterococci*	TET^R *Enterococci*/ Total *Enterococci*	TY^R *Enterococci*/ Total *Enterococci*
Essential Oil	P = 0.622	P = 0.133	P = 0.450	P = 0.185
Yes	0.52	0.94	0.73	0.89
No	0.52	0.94	0.72	0.87
Forage Concentration	P = 0.073	P = 0.519	P = 0.686	P = 0.357
80%	0.08	0.75	0.23	0.55
47%	0.11	0.74	0.23	0.58
14%	0.22	0.68	0.27	0.53

cline (TET)-resistant *Escherichia coli* and tylosin (TY)- and TET-resistant *Enterococci spp*.—in freshly excreted manure and consolidated pen surface material from a beef feedlot operation.

Procedure

This study was conducted at the Eastern Nebraska Research and Extension Center (ENREC), near Mead, NE. Four-hundred, twenty beef cattle were assigned to 42 pens with each pen assigned randomly to one of six treatments: feed containing 14%, 47% or 80% corn silage with or without essential oil supplement. The remainder of the diet consisted of dry-rolled corn, 16% wet distillers' grains, monensin (30 g/ton), and tylosin (Tylan®) (90 mg/steer/day). Samples of freshly-excreted cattle manure and consolidated feedlot surface material from two areas of each pen—near waterers and at the backs of pens—were retrieved from each pen four times (February through June) during the finishing period. Samples were spiral-plated in duplicate on agar to select for four types of antibiotic resistant bacteria: azithromycin (AZ^R)- and tetracycline (TET^R)-resistant *Escherichia coli* and tylosin (TY^R)- and TET^R-resistant *Enterococci*. Colony-forming units per gram of sample were enumerated by manual plate counting.

Results and Discussion

Examination of the ratio of AR bacteria to total bacterial concentration (Table 1 and Table 2) reveals that the concentration of TY^R *Enterococci* and AZ^R *E.coli* were quite high relative to the measured total concentration of each bacteria in samples throughout this study. These high concentrations are not surprising given that the animals were fed tylosin, which suggests that bacteria with resistance to tylosin would have had an advantage over other bacteria. Perhaps more surprising is that AR bacteria were present in all the manure samples collected in this study, including bacteria that were resistant to antibiotics not administered to the animals (tetracycline) indicating either a certain degree of baseline resistance must be expected or an environmental selection for tetracycline resistance not directly related to antibiotic use.

When the impact of dietary forage concentration was averaged for both presence and absence of essential oils TET^R *E.coli* showed significant (α=0.05) differences due to forage concentration in both the freshly excreted manure and pen surface material (Table 1). In freshly excreted manure the mean ratio of TET^R *E.coli* was lower in manure samples from pens where cattle received a 14% forage diet and the highest bacterial concentrations in manure from cattle receiving a 80% forage diet. However in consolidated pen surface material the mean ratio of TET^R *E.coli* was lowest in samples from pens where cattle received an 80% forage diet and highest in samples from cattle receiving a 47% forage diet, the 14% diet was not significantly different from either of the two higher concentration diets. The results of this study indicate that a beef cattle finishing diet low in dietary forage concentration produces the same effect on AR bacteria concentrations in manure as high forage, and in one population (TET^R *E.coli* in pen fresh manure) a low dietary forage concentration was the most effective for reducing AR in manure.

Inclusion of a proprietary blend of essential oils to the finishing diets of cattle in this study did not impact any of the AR bacterial concentrations in freshly excreted manure or consolidated feedlot pen surface material (Table 1 and 2).

Implications/Conclusions

The results of this research indicate that beef finishing diets with low silage concentrations (14%) are equally or more effective than diets with higher silage concentrations for reducing AR bacteria concentrations in manure. The presence of bacteria resistant to antibiotics not given to the animals during the study also indicates that co-selection for multiple resistances inside the animal's digestive tract or environmental factors at the feedlot may have more impact on AR in manure than dietary treatments. Furthermore, because there was little impact by dietary changes on AR bacteria in manure, it will be important to continue to examine manure treatment, storage and application strategies that may mitigate potential human health risks from manure-borne AR bacteria.

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Antibiotic Resistance in Manure-Amended Agricultural Soils

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Summary with Implications

Manure application to agricultural land benefits soil health and agronomic yields. However, as antibiotic resistance becomes a more serious threat to public health, there is concern that antibiotic resistance originating from livestock manure could impact human health through contamination of the environment or food. This study sought to quantify this risk by monitoring concentrations of antibiotic resistance bacteria and genes in fallow soil during the period of October through April, representing fall manure application through spring planting. Resistance to three common antibiotics—tylosin, azithromycin and tetracycline—was monitored following application of fresh, stockpiled, or composted beef feedlot manure, or inorganic fertilizer. Overall, concentrations of all monitored resistant bacteria were below the detection limit for enumeration. Results indicate that while all the manure treatments increased at least one measure of antibiotic resistance during the sampling period, by the final sampling day antibiotic resistance prevalence and concentrations in manured plots were not significantly different from soil receiving no fertilizer treatments.

Procedures

This study was conducted at the University of Nebraska's Rogers Memorial Farm (RMF) east of Lincoln, NE. The RMF is a no-till crop research farm, the soil at this site was an Aksarben silty clay loam had no recent history of manure application; the field had been planted in soybeans in 2018, as the first year of a four-year rotation of soybeans, corn, winter wheat, and sorghum (milo). Twenty plots (10 ft × 15 ft) were randomly assigned to one of five experimental treatments: fresh beef feedlot manure (20 tons/ac), composted beef manure (20 tons/ac), stockpiled beef manure (20 tons/ac), inorganic fertilizer (N:P:K at 15-23-10 sufficient to apply 140 lb/ac), and a control (no amendment). Fresh manure for the study was sourced from the feedlot at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE from animals that had been fed tylosin (90 mg steer^{-1} day^{-1}) for disease prevention. The stockpiled manure and composted manure originated at the USDA US Meat Animal Research Center (USMARC) near Clay Center, NE from previous a study monitoring antibiotic resistance levels in manure during manure storage. All of the treatments were broadcast by hand to the surfaces of the study plots according to the mass/area measurements described in Table 1 and left unincorporated.

Soil was sampled from all plots once before and after treatment applications in October and then monthly through April. Each sample consisted of a composite of four 4-in deep cores obtained at random locations of each plot using a soil probe (2-in diameter), crop residue and treatment applications was brushed away before collecting soil with the soil probe. Soil probes were sterilized between each plot using a 70% ethanol solution. Samples were analyzed for prevalence (proportion of samples containing resistant species) and enumeration (total number of resistant cells or genes within the sample) of both live resistant bacteria [azithromycin (AZ^R)- and tetracycline (TET^R)-resistant *Escherichia coli* and tylosin (TY^R)- and TET^R-resistant *Enterococci*] and genes that convey resistance [*tetO, tetQ, ermB*].

Table 1. Properties of fertilizer amendments

Treatment Type[1]	Fresh Beef Feedlot Manure	Composted Beef Feedlot Manure	Stockpiled Beef Feedlot Manure	Inorganic Fertilizer (15-23-10)	Control
Application Rate	20 ton/ac	20 ton/ac	20 ton/ac	900 lb/ac	N/A
N Rate (lbs/ac)	110	28	28	141	0
P_2O_5 Rate (lbs/ac)	460	600	780	216	0
K_2O Rate (lbs/ac)	600	660	680	94	0
Prevalence AR Bacteria (%)	100	6–12	0–30	0	0
Concentration 16S (log copies g^{-1} d.w.)	nd	8.9	8.7	0	0
Concentration *ermB* (log copies g^{-1} d.w.)	nd	3.6	4.3	0	0
Concentration *tetO* (log copies g^{-1} d.w.)	nd	4.2	4.3	0	0
Concentration *tetQ*[1] (log copies g^{-1} d.w.)	nd	4.8	4.7	0	0

[1] Concentrations of AR genes and bacteria in amendments as reported in preceding studies. PCR was not conducted on fresh manure samples so there is no direct measure of AR genes in the samples, but fresh manure was assessed for presence of AR bacteria. AR *E.coli* and *Enterococci* were found in all of the 50+ samples of fresh manure analyzed prior to land application.

Results and Discussion

Throughout the study, samples from control plots consistently contained antibiotic resistant (AR) bacteria and AR genes, which is expected since these elements are naturally occurring in the soil environment.

The prevalence of AR bacteria increased immediately following application of fresh and stockpiled manure treatments to the soil but returned to the same prevalence as control plots by the end of the study. Moreover, because all the genes and AR bacteria considered in this study were also observed in soil from control plots, it becomes more challenging to determine the true AR contribution of the treatments. Possibly the increasing changes observed were fluctuations in the native resistant populations responding to environmental conditions and an influx of nutrients in the fertilizers, especially in the carbon-rich manures. Future work should conduct background studies of the native fluctuations of resistance species responding to the crop management and environmental conditions which could provide more insight into the source and nature of the resistance in soil at the site.

The only treatment that significantly impacted AR genes was composted manure, which increased overall *ermB* concentration. However, as with AR bacteria, the AR gene concentration in plots receiving composted manure returned to control levels by the end of the study. Further studies should consider why the plots receiving composted manure had the highest prevalence of *ermB* despite composted manure having the lowest initial concentration of *ermB* genes of any of the manure treatments applied (Table 1). This may be because the cells that managed to survive the composting process had other survival mechanisms, such as endospore formation, that made them more capable of surviving in the harsher soil environment than other native fecal bacteria. Future research should thus incorporate metagenomic analysis to determined which species were responsible for transfer of genes to soil bacteria form manure.

Implications/Conclusions

Soils, whether influenced by human actions or not, contain naturally-occurring antibiotic resistant bacteria and antibiotic resistance genes. Application of carbon-rich manures may initially increase AR indicators in agricultural soils, but the effect lessens over time. Based on the results of this study, a fall application of manure would not significantly increase the risk of transferring AR bacteria or genes to crops planted in the spring.

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Statistics Used in the Nebraska Beef Cattle Report and Their Purpose

The purpose of beef cattle and beef product research at UNL is to provide reference information that represents the various populations (cows, calves, heifers, feeders, carcasses, retail products, etc) of beef production. Obviously, the researcher cannot apply treatments to every member of a population; therefore he/she must sample the population. The use of statistics allows the researcher and readers of the Nebraska Beef Cattle Report the opportunity to evaluate separation of random (chance) occurrences and real biological effects of a treatment. Following is a brief description of the major statistics used in the beef report. For a more detailed description of the expectations of authors and parameters used in animal science see Journal of Animal Science Style and Form at: http://jas.fass.org/misc/ifora.shtml.

—**Mean:** Data for individual experimental units (cows, steers, steaks) exposed to the same treatment are generally averaged and reported in the text, tables and figures. The statistical term representing the average of a group of data points is mean.

—**Variability:** The inconsistency among the individual experimental units used to calculate a mean for the item measured is the variance. For example, if the ADG for all the steers used to calculate the mean for a treatment is 3.5 lb then the variance is zero. But, this situation never happens! However, if ADG for individual steers used to calculate the mean for a treatment range from 1.0 lb to 5.0 lb, then the variance is large. The variance may be reported as standard deviation (square root of the variance) or as standard error of the mean. The standard error is the standard deviation of the mean as if we had done repeated samplings of data to calculate multiple means for a given treatment. In most cases treatment means and their measure of variability will be expressed as follows: 3.5 ± 0.15. This would be a mean of 3.5 followed by the standard error of the mean of 0.15. A helpful step combining both the mean and the variability from an experiment to conclude whether the treatment results in a real biological effect is to calculate a 95% confidence interval. This interval would be twice the standard error added to and subtracted from the mean. In the example above, this interval is 3.2–3.8 lb. If in an experiment, these intervals calculated for treatments of interest overlap, the experiment does not provide satisfactory evidence to conclude that treatments effects are different.

—***P* Value:** Probability (*P* Value) refers to the likelihood the observed differences among treatment means are due to chance. For example, if the author reports $P \leq 0.05$ as the significance level for a test of the differences between treatments as they affect ADG, the reader may conclude there is less than a 5% chance the differences observed between the means are a random occurrence and the treatments do not affect ADG. Hence we conclude that, because this probability of chance occurrence is small, there must be difference between the treatments in their effect on ADG. It is generally accepted among researchers when *P* values are less than or equal to 0.05, observed differences are deemed due to important treatment effects. Authors occasionally conclude that an effect is significant, hence real, if *P* values are between 0.05 and 0.10. Further, some authors may include a statement indicating there was a tendency or trend in the data. Authors often use these statements when *P* values are between 0.10 and 0.15, because they are not confident the differences among treatment means are real treatment effects. With *P* values of 0.10 and 0.15 the chance random sampling caused the observed differences is 1 in 10 and 1 in 6.7, respectively.

—**Linear & Quadratic Contrasts:** Some articles contain linear (L) and quadratic (Q) responses to treatments. These parameters are used when the research involves increasing amounts of a factor as treatments. Examples are increasing amounts of a ration ingredient (corn, by-product, or feed additive) or increasing amounts of a nutrient (protein, calcium, or vitamin E). The L and Q contrasts provide information regarding the shape of the response. Linear indicates a straight line response and quadratic indicates a curved response. P-values for these contrasts have the same interpretation as described above.

—**Correlation (r):** Correlation indicates amount of linear relationship of two measurements. The correlation coefficient can range from -1 to 1. Values near zero indicate a weak relationship, values near 1 indicate a strong positive relationship, and a value of -1 indicates a strong negative relationship.

Animal Science
http://animalscience.unl.edu

Curriculum: The curriculum of the Animal Science Department at the University of Nebraska–Lincoln is designed so that each student can select from a variety of options oriented to specific career goals in professions ranging from animal production to veterinary medicine. With unique opportunities to double major in ***Grazing Livestock Systems*** (http://gls.unl.edu) or complete the ***Feedlot Management Internship Program*** (http://feedlot.unl.edu/intern)

Careers:

Animal Health
Banking and Finance
Animal Management
Consultant
Education
Marketing
Technical Service
Meat Processing
Meat Safety
Quality Assurance
Research and Development
Veterinary Medicine

Scholarships: The Animal Science Department also offers scholarships to incoming freshmen and upperclassmen. The department awards over $30,000 each year to Animal Science students.

ABS Global Scholarship
Baltzell-Agri-Products, Inc. Scholarship
Maurice E. Boeckenhauer Memorial Scholarship
Mike Cull Judging and Activities Scholarship
Don Geweke Memorial Award
Parr Young Senior Merit Award
Nebraska Pork Producers Association Scholarship
Waldo Family Farms Scholarship
Frank and Mary Bruning Scholarship
Art and Ruth Raun Scholarship
Animal Science Department Freshman Scholarship
Feedlot Management Scholarship
Robert Boeckenhauer Memorial Scholarship
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Max and Ora Mae Stark Scholarship
D. V. and Ernestine Stephens Memorial Scholarship
Dwight F. Stephens Scholarship
Arthur W. and Viola Thompson Scholarship
Thomas H. Wake, III Scholarship
Frank E. Card Scholarship
Derrick Family Scholarship
G. H. Francke Livestock Judging Scholarship
Eric Peterson Memorial Award
Winkler Memorial Livestock Judging Scholarship

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