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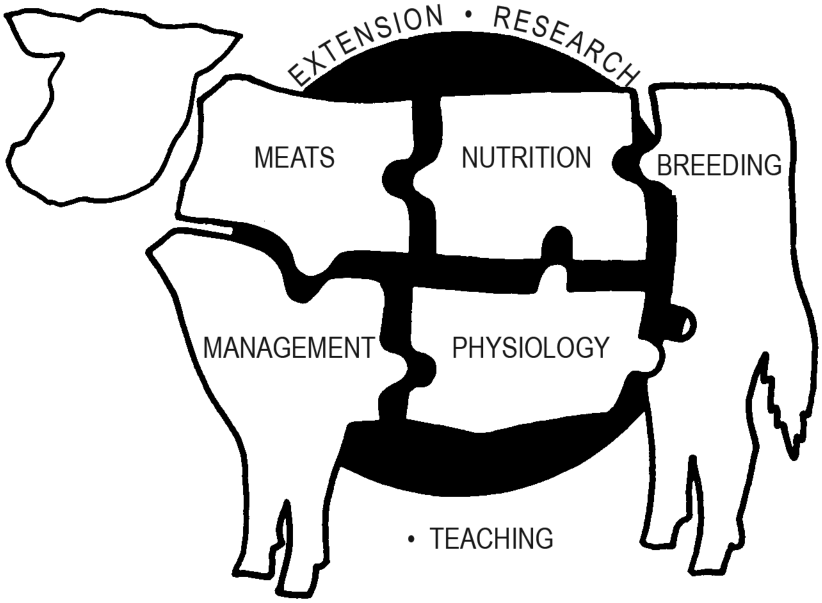

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Beef Cattle Report

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The Effect of Cow Udder Score on Subsequent Calf Performance in the Nebraska Sandhills

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Rick N. Funston
J. Travis Mulliniks

Summary with Implications

Cow records were evaluated over a 5-yr period to investigate how cow udder score affected calf growth and carcass performance. Cows from 2 calving herds, March and May, were classified as bad or good based on udder scores recorded at calving. Calves suckling dams with bad udders performed similarly during the pre-weaning period to good udder counterparts, with no differences in overall steer feedlot performance between udder groups. However, steers suckling good udder cows had heavier carcass weights and greater back fat thickness.

Introduction

Selection pressure for increased production has caused producers to remove cows from their herd for reproductive failure, structural issues, poor health, and disease. Producers emphasize improved growth by selecting genetically superior animals through increased milk yield and calf growth. However, beef cows with poor udder conformation may decrease production through decreased calf body weight at weaning and increased labor costs. Research has shown defects in teat shape and size inhibits nursing ability thus negatively impacting calf intake and gain. Contradictory findings have reported calves suckling dams with just one functional teat have similar growth performance in comparison with calves suckling dams with all functional teats. Thus, it was hypothesized cows classified with poor udders would produce calves with similar pre- and post-weaning growth. The objective of this study was to evaluate the effect of beef cow udder score within March and May calving seasons on pre- and post-weaning progeny performance.

Table 1. Effect of cow udder score on calf growth from birth to weaning

	Treatments[1]			
Item	BU	GU	SEM	*P*-value
Birth BW (lb)	71	71	1.11	0.95
Weaning BW(lb)	451	446	7	0.40
Adj. 205 d BW(lb)	340	345	7	0.28

[1]Treatments are BU (udder score of 1 or 2) and GU (udder score of 3 or 4).

Procedure

Cow and calf performance data on 812 cows were collected from 2013 through 2017 at the Gudmundsen Sandhills Laboratory (Whitman, NE). Cow and subsequent calf performance were obtained from the March (n = 500) and May (n = 312) calving herds at Gudmundsen Sandhills Laboratory. Each year at calving, udder scores were recorded from a 1 (bad) to 5 (good) as reported in the Integrated Resource Management Guide (National Cattlemen's Beef Association, 2013). The udder score combines udder conformation and a teat score system. Cows were grouped by udder scores and classified as either BU (bad udder score 1 or 2, n = 223) or GU (good udder score 3 or greater, n = 1,742). Calf data were stratified by cow udder score, calving season, and year.

Calves were vaccinated at 2 mo of age with an infectious bovine rhinotracheitis, parainfluenza-3 virus, bovine respiratory syncytial virus, and bovine viral diarrhea type I and II vaccine (BoviShield 5, Zoetis, Florham Park, NJ). Calves were also weighed, branded, and male calves were castrated. Cow-calf pairs grazed native upland range pastures. At weaning, calves were weighed and vaccinated against bovine rotavirus-coronavirus clostridium perfringens type C and D and Escherichia (Bovine Rota-Coronavirus Vaccine, Zoetis, Florham Park, NJ). After weaning, March-born steers were placed in a drylot and consumed ad libitum hay for 2 wk, transported to the West Central Research and Extension Center (WCREC), and fed as a group in drylot pens.

After weaning, May-born steers grazed subirrigated meadow with 1.0 lb supplement or received ad libitum hay with 4.0 lb supplement until approximately 1 yr of age then relocated to WCREC. Steers were placed in a GrowSafe feeding system approximately 2 weeks after arrival at WCREC. Following a 10-d acclimation period in the GrowSafe, steers were weighed 2 consecutive d and the average was the initial feedlot entry BW used in calculating feedlot performance. All steers experienced a 21 d transition period to a common finishing diet of 48% dry rolled corn, 40% corn gluten feed, 7% prairie hay, and 5% supplement. All steers were implanted with 14 mg estradiol benzonate and 100 mg trenbolone acetate (Synovex Choice, Zoetis) at feedlot entry. Approximately 100 d before slaughter, calves were implanted with 28 mg estradiol benzoate and 200 mg trenbolone acetate (Synovex Plus, Zoetis). Each year, steers were slaughtered at a commercial facility (Tyson Fresh Meats, Lexington, NE) when estimated visually to have 1.3 cm fat thickness over the 12th rib. Carcass data were collected 24 h post slaughter and final BW was calculated from HCW based on an average dressing percentage of 63%. Carcass data included HCW, marbling, yield grade, backfat, and LM area.

Data were analyzed using the PROC MIXED and GLIMMIX procedures of SAS (SAS Inst. Inc., Cary, NC). A mixed model ANOVA accounted for correlations within udder score and udder score within calving season. Models included the effect of treatment, cow age, calving season, and calf sex for all appropriate data. Data are presented as LSMEANS and *P*-values ≤ 0.05 were considered significant and tendencies were considered at a $P > 0.05$ and $P \leq 0.10$.

Results

There were no interactions between calving seasons or year, therefore the main effect of udder score is reported. Calf BW at birth, weaning, and adjusted 205-d BW is reported in Table 1. Influence of sex was not significant in any of the parameters ($P \geq 0.10$), thus, heifer and steer data were pooled together in all pre-weaning variables. Calf BW at birth was similar between udder score groups ($P = 0.95$), along with calf weaning BW ($P = 0.40$) and adjusted 205-d BW ($P = 0.28$). Steer feedlot performance is reported in Table 2. Steers from bad udder (BU) and good udder (GU) dams had similar feedlot entry BW ($P = 0.41$), final feedlot BW ($P = 0.30$), DMI ($P = 0.54$), ADG ($P = 0.60$), and F:G ($P = 0.71$). Carcass performance is reported in Table 3. Calves suckling GU dams had greater HCW ($P = 0.04$) and backfat ($P = 0.02$) compared with BU counterparts. Although feedlot entry and final BW were similar for steers from GU and BU dams, they were numerically greater for steers from GU dams, which may have increased HCW.

Table 2. Effect of cow udder score on steer feedlot performance

	Treatments[1]			
Item	BU	GU	SEM	*P*-value
Entry BW (lb)	595	610	18	0.41
Final BW (lb)	1,364	1,388	22	0.30
DMI (lb/d)	27.6	27.2	0.55	0.53
ADG (lb)	3.69	3.76	0.07	0.60
F:G	7.13	7.24	0.31	0.71

[1] Treatments are BU (udder score of 1 or 2) and GU (udder score of 3 or 4).

Table 3. Effect of cow udder score on calf carcass traits

	Treatments[1]			
Item	BU	GU	SEM	*P*-value
HCW (lb)	829	860	15	0.04
Yield Grade	2.3	2.7	0.20	0.10
LM area (in^2)	13.9	14.1	0.29	0.63
Marbling Score[2]	454.5	461.2	23.2	0.85
Backfat (in)	0.50	0.57	0.03	0.02

[1] Treatments are BU (udder score of 1 or 2) and GU (udder score of 3 or greater).

[2] Marbling score: 400 = Small^{00}, 450 = Small^{50}, 500 = Modest^{00}

Conclusion

Though udder score doesn't have a large impact on pre-weaning calf growth performance, an advantage of carcass weight in calves born to GU cows suggests a positive impact on processing yield for consumer products. Further research is required to define how udder score affects female progeny and how calving season influences the total proportion of BU cows.

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Economic Analysis of Beef Systems

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Summary with Implications

Economic analysis of complete beef production systems is important. An analysis of 5 systems was conducted. Three of the systems were based on cows calving in March, June or August and grazing Sandhills range and corn residue. The other 2 systems were based on complete confinement feeding or confinement in the summer and corn residue grazing in the winter. The range-based systems gave similar results, however, complete confinement was not competitive. Partial confinement with stalk grazing was competitive with range-based systems. Stalk grazing is very economical and important for many cow-calf systems.

Introduction

Each individual cow-calf operation has unique feed resources available, mostly forages. How these resources are used influences both the cattle performance and the economics. Nebraska is blessed with excellent grass resources, but the acres of these resources are declining. The resources increasing are corn residues and ethanol by-products. How these resources fit into complete production systems is very important.

Beef systems research is important and useful but challenging. We are fortunate at Nebraska to have excellent facilities with which to conduct systems research. Further, there has been good support for team research at both the Gudmundsen Ranch (GSL) and the Eastern Nebraska Research and Development Center (ENREC). Our objective was to conduct an economic analysis of a range of beef systems based on research conducted at GSL and ENREC.

Table 1. Costs used in economic analysis

Grazing Pasture	$50/pair/month
Cornstalk Grazing	$18/acre
Corn Grain	$0.094/lb DM
Distillers Grains	$0.094/lb DM
Sweet Bran	$0.094/lb DM
Grass Hay	$0.044/lb DM
Stalks or Straw	$0.042/lb DM
Mineral	$10/year/pair
Cow depreciation, interest and breeding	$275/year
Feedlot Yardage	$0.45/d/calf-fed
Dry lot Yardage	$0.50/d/pair
Grazing yardage	$0.10/d/cow
Supplemental yardage[1]	$0.20/d/cow
Stalk grazing yardage[2]	$0.25/d/cow
Finishing interest	6.2%
Weaning rate	90%

[1] Cost when cows supplemented while grazing

[2] Includes fencing and supplementing

Procedure

Griffin and others reported on a 4 year systems project at GSL which included wintering system and calving date (136 cows per year). The steers were fed out at West Central Research and Extension Center (WCREC; 2010 Nebraska Beef Cattle Report, pp. 5–7). The pairs grazed Sandhill's range in the summer and corn residue in the winter. Cows were supplemented with approximately 1 lb of a distillers grains based cube daily while grazing corn residue. Cows calved in March, June or August. Calves were weaned in October (March-born) or April (June- and August-born) and preconditioned at the ranch before being shipped to the feedyard. March, June and August calves were 240, 298 and 247 days of age upon entering the feedyard.

Loeffelholz et al. (2019 Nebraska Beef Cattle Report, pp. 25–28) have reported a 3 year systems study conducted at ENREC. Cows were fed in confinement year-round or were in confinement during the summer and grazed corn residue in the winter. Pairs were supplemented with approximately 5.3 lb of a distillers grains based cube daily while grazing corn residue. Cows calved in early July and calves were weaned in April. Weaning occurred when pairs were removed from corn stalks. Calves were weaned directly into the feedyard at 276 days of age.

Only the steer calves were fed in each of the systems studied, therefore, the feedlot performance data are for the steers only. The finishing diets were similar at WCREC and ENREC with 30 to 40% Sweet Bran, 0 to 10% distillers, and dry-rolled corn or a combination of dry-rolled and high-moisture corn. After harvest, data were adjusted to a 63% dress and to 0.5 inches 12th ribfat thickness.

For the economic analysis, costs were based on a 10-year average of prices (Table 1). A 90% weaning rate was assumed for all 5 systems. Stalk intake for pairs was assumed to be 20% greater than for dry cows.

Results

Unit cost of production (breakeven) was similar for the 3 systems representing typical production in the Sandhills (Table 2). However, final body weights of the steers were greater for the calves born in June and August compared to those born in March. The extra weight is due to greater age at weaning resulting in heavier weights into the feedyard. This resulted in greater net return for the steers born in June.

Cows and calves maintained in complete confinement had greater unit costs of production and had a net loss. On average, the cost of the feed and yardage is not competitive with grazing systems. However, the least expensive source of feed is grazed corn residue. By making use of this resource, the system of confinement in the summer and stalk grazing until April in the winter was competitive with the more traditional systems.

The availability of grass declined some in the past few years and therefore, price of grass for grazing has increased. The GSL systems research has emphasized the importance of allowing the cattle to graze minimizing harvest and feeding costs. This is very important in controlling costs, but there is still a significant cost to the grass. Alternative feedstuffs in high supply include corn, corn silage, distillers grains and harvested residues. However, there is a cost to feeding these harvested feeds as illustrated by the high costs for the complete confinement system.

The feed resource in great supply is corn residue. As corn production (acres and yield) increases, the amount of residue increases as well. Combining stalk grazing with confinement made that system competitive. This may fit in many areas of the state, but especially in high corn-producing areas with minimal pasture.

It is notable that the June, July, and August calving systems involved allowing the calves to nurse longer than 240 days while the pairs grazed stalks. This produced heavier weaning weights and slaughter weights. Further, as calf-feds, these calves came to market at a time during the year when prices are usually greater than those received from the earlier weaned (March-born) calves. This difference was not accounted for in the economic analysis.

Table 2. Economics of 5 different cow-calf production systems

	March[1]	June[1]	August[1]	Conf.[1]	Stalk[1]
Cow costs, $/cow	908.18	932.59	926.98	1133.07	974.99
Precon[2], $/calf	15.00	24.00	24.00	10.00	10.00
Feed[3], $/calf	421.40	465.77	462.95	365.38	404.58
Interest[3], $/calf	42.44	40.47	42.57	43.72	39.21
Yardage[3], $/calf	97.65	90.90	95.85	83.70	91.35
Total costs, $/calf	1484.67	1553.73	1552.35	1635.87	1520.13
Final Live BW, lb	1313	1390	1355	1382	1367
UCOP[4], $/lb live BW	1.131	1.118	1.146	1.184	1.112
Net Profit, $/calf	25.28	44.77	5.90	-46.57	51.92

[1] March = calves born in March, pairs grazed Sandhill's range in the summer and corn residue in the winter

June = calves born in June, pairs grazed Sandhill's range in the summer and corn residue in the winter

August = calves born in Aug, pairs grazed Sandhill's range in the summer and corn residue in the winter

Conf. = confinement of pairs in dry lot year round

Stalk = confinement of pairs in dry lot during the summer and grazing corn residue in the winter

[2] Preconditioning

[3] Feedyard costs

[4] Unit cost of production, 10 year average selling price = $1.15 per lb.

Conclusions

There are many interacting factors in estimating the economics of beef systems. These analyses suggest that the use of grazed corn residue has the potential to increase net returns in beef systems, especially in intense corn producing areas of the state. The complete system analysis suggests delayed weaning while pairs grazed corn residue enhances net income because the fed steers weighed more at harvest.

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Effects of Prepartum Nutrition on May-Calving Cows and Progeny

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Summary with Implications

May-calving dams grazed either sub-irrigated meadow or upland range from Jan. 5 to May 1 each year for 6 years. Within grazing system, dams received either no supplement or 1 lb/d of a 33% CP supplement from Jan. 5 to April 1. Dams grazing meadow in the prepartum period weighed more and had a greater body condition score prior to calving. They also tended to have greater pregnancy rates in the subsequent breeding season and tended to wean heavier calves than dams grazing upland range. Allowing May-calving dams to graze meadow in late gestation may increase herd profitability through increased dam pregnancy rates and weaned calf value. Furthermore, supplemented dams weaned heavier calves, independent of grazing system. Supplementation of May-calving dams in late gestation may be economical if the income from additional pounds of calf weaned is greater than the supplementation cost.

Table 1. Nutrient analysis and composition on a DM basis of supplement provided to May-calving cows in late gestation[1]

Item	
Nutrient	
CP, %	32.9
RUP, % CP	39.7
TDN, %	78.4
Ingredient, % DM	
Dried distillers grains meal	52.5
Soybean meal (46.5% CP)	14.7
Vitamin and mineral package[3]	13.3
Wheat middlings	6.3
Sunflower meal (35% CP)	6.3
Molasses, liquid	3.7
Urea	1.6
Cull beans	1.5

[1] May-calving dams were assigned to 1 of 2 supplementation groups for 85 d: 1 lb/d of supplement (S) or no supplement (NS) beginning at weaning in January.

[2] Calculated using the equations proposed by the NRC, 2000.

[3] Formulated to provide 0.7 g/lb monensin (Rumensin, Elanco Animal Health).

Introduction

Previous research (*2006 Nebraska Beef Cattle Report*, pp. 7–9; *2009 Nebraska Beef Cattle Report*, pp. 5–8) examined increasing dietary CP and TDN for March-calving cows in late gestation and determined no difference in rebreed pregnancy rates. Late gestation for a March-calving herd occurs when forage is dormant, low in crude protein (CP) and *in vitro* dry matter digestibility (IVDMD), and supplementation may not have been enough to meet cow nutrient requirements. Alternately, late gestation for a May-calving herd occurs during early forage growth, where forage can meet or exceed the dam's nutrient requirements. Furthermore, differences in forage species composition between upland range and subirrigated meadow (cool vs. warm season) result in different growth patterns and forage quality. The increased forage availability and quality during the prepartum period of a May-calving herd can affect maternal productivity, as well as progeny postnatal growth and performance. The objective of this study was to evaluate the effect of grazing system with and without supplementation on May-calving dam reproductive performance and progeny growth through weaning.

Procedure

Dam Management

Multiparous, May-calving cows (n = 652, 928 ± 4 lb) were blocked by BW and arranged in a 2 × 2 factorial treatment at weaning in January. Dams grazed either upland range (R) or sub-irrigated meadow (M). Within grazing treatment, cows were randomly assigned to receive either no supplement (NS) or 1 lb/d of a 33% CP supplement (S, Table 1). Grazing treatment continued for 116 ± 2 d (mean ± SD) while supplementation treatment continued for 85 ± 2 d (mean ± SD). Range sites were stocked at 0.6 AUM, whereas sub-irrigated meadow was stocked at 3 AUM.

Dietary CP and TDN as a percentage of dam requirements for each treatment combination are presented in Table 2. Dam BW and body condition score (BCS, 1 = emaciated to 9 = obese) were recorded at initiation and conclusion of grazing treatment. After the treatment period, dams were managed as a single herd grazing upland range the remainder of the year. At parturition, progeny birth BW, sex, and birth date were recorded. Dams were assigned a calving ease (CE) score (1 = no assistance, 2 = easy assist, 3 = difficult assist, and 4 = caesarian section) at parturition, with scores of 2 or greater considered dystocia.

In July, dams were placed with fertile bulls at a ratio of 1:20 (bull:dam) for a 45 d breeding season. Five d after bull placement, dams were synchronized with a single $PGF_{2\alpha}$ injection (5 mL i.m. Lutalyse, Zoetis, Parsippany, New Jersey). In early January, dams were diagnosed for pregnancy via rectal palpation or transrectal ultrasonography and calves weaned. Calf BW was recorded at pre-breeding and weaning.

Statistical Analysis

All data were analyzed using the PROC GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC, version 9.4). The model statement included the fixed effects of dam grazing treatment, supplementation treatment, and the resulting interaction. The experimental unit was considered grazing system × supplementation treatment × yr. Dam age and yr were included as a covariate in all analyses and were removed when $P > 0.05$. Data were considered significant

Table 2. Predicted[1] nutrient composition as a percentage of requirements in diets offered to May-calving dams in late gestation[2]

	Meadow		Range	
	NS	S	NS	S
January				
CP, % mid-gestation req.[3]	85.9	95.8	70.4	80.3
NEm, % mid-gestation req.[4]	96.9	99.0	118.4	120.4
February				
CP, % late gestation req.[5]	139.2	146.8	73.8	82.3
NEm, % late gestation req.[6]	76.4	79.1	104.5	106.4
March				
CP, % late gestation req.	251.9	255.7	153.2	159.5
NEm, % late gestation req.	143.6	143.6	143.6	143.6
April				
CP, % late gestation req.	320.7	322.8	160.3	167.1
NEm, % late gestation req.	144.5	144.5	156.4	156.4

[1] Diet composition predicted using a computer model based on NRC, 2000 equations.

[2] May-calving dams were arranged in a 2 × 2 factorial at weaning in January and were assigned to 1 of 2 grazing treatments: sub-irrigated meadow (M) or upland range (R) for 116 d and then to 1 of 2 supplementation treatments: 1 lb/d of 33% CP (DM) supplement (S) or no supplement (NS) for 85 d.

[3] CP expressed as a percentage of requirement for mid-gestation multiparous dams (7.1% CP, DM; NRC, 2000).

[4] NEm expressed as a percentage of the requirement for mid-gestation multiparous dams (0.45 Mcal/lb; NRC, 2000).

[5] CP expressed as a percentage of requirement for late gestation multiparous dams (7.9% CP, DM; NRC, 2000).

[6] NEm expressed as a percentage of the requirement for late gestation multiparous dams (0.50 Mcal/lb; NRC, 2000).

at $P \le 0.05$ and a tendency if $P \le 0.10$ and $P > 0.05$.

Results

Over the treatment period, there was a grazing system × supplement interaction ($P = 0.02$, Table 3) for dam BW change. Dams allotted to the MS treatment had the greatest BW gain, MNS intermediate, followed by RS dams, and RNS dams. This resulted in differences in prepartum BW between grazing treatments and supplementation treatments. Dams grazing meadow had a greater ($P < 0.01$) prepartum BW when compared with R dams (1,036 vs. 1,005 ± 7 lb, M vs. R). Likewise, S dams had a greater ($P < 0.01$) prepartum BW than NS dams (1,034 vs. 1,005 ± 7 lb, S vs. NS). Increased dam BW is likely a result of increased diet quality (Table 2).

Grazing treatment did not affect ($P \ge 0.78$) prepartum BCS or BCS change during treatment. Conversely, dam supplementation increased ($P < 0.01$) prepartum BCS (4.7 vs. 4.6 ± 0.03, S vs. NS). Change in BCS during the prepartum period is an indicator of pregnancy success in the upcoming breeding season, with dams who increase or maintain BCS having greater pregnancy rates than dams who lose BCS. It is important to note supplemented dams in this study gained ($P < 0.01$) BCS over the treatment period, but NS dams did maintain condition (0.2 vs. 0.0 ± 0.03, S vs. NS).

Prepartum supplementation did not affect ($P = 0.48$) dam rebreed pregnancy rates. Prepartum meadow grazing tended ($P = 0.08$) to increase subsequent pregnancy rates (89 vs. 85 ± 2%, M vs. R), despite no difference in prepartum BCS. Recent research has shown feeding dams a high energy diet prepartum increased activation of metabolic pathways involved in triglyceride synthesis in the postpartum period (Shahzad et al., 2014, https://doi.org/10.1371/journal.pone.0099757). It is possible dams grazing meadow prepartum had an altered metabolic response and may have been primed to better utilize nutrients in the subsequent breeding season.

At parturition, dystocia rate was not affected ($P \ge 0.14$) by treatment, although both grazing treatment and supplementation affected calf birth BW. Calves born to dams who grazed meadow tended ($P = 0.07$) to have an increased birth BW (74 vs. 72 ± 0.4 lb, M vs. R). Additionally, calves born to supplemented dams had increased ($P = 0.04$) birth BW (74 vs. 72 ± 0.4 lb, S vs. NS). At pre-breeding, there was a tendency for a grazing system × supplement interaction ($P = 0.09$) in calf BW, with RS calves having the greatest BW, MS and MNS intermediate, and RNS having the lowest BW. At weaning, calves born to dams grazing meadow in the prepartum period tended ($P = 0.09$) to have increased BW (443 vs. 436 ± 2 lb, M vs. R). Similarly, prepartum supplemented dams weaned heavier calves ($P = 0.02$; 443 vs. 434 ± 2 lb, S vs. NS). Larson et al. (*2009 Nebraska Beef Cattle Report*, pp. 5–8) observed an increase in milk production for March-calving cows grazing corn residue in late gestation when compared with cows grazing winter range. It is possible increased dietary nutritive value in late gestation is responsible for increased milk production and consequent calf BW.

Conclusions

May-calving dams grazing sub-irrigated meadow had increased prepartum BW and BCS. Furthermore, they tended to have increased pregnancy rates in the following breeding season and wean heavier calves. Allowing May-calving dams to graze meadow during late gestation may increase total herd profitability through increased stayability of dams and increased weaned calf value. Independent of grazing system, supplemented dams had increased prepartum BW and BCS. Progeny birth and wean BW were also increased by prepartum supplementation, with no effect on dystocia rate. The cost of supplementation provided to May-calving dams in late gestation should be balanced against that additional 9 lb of calf weaned observed in the current study. This research indicates management decisions made in one segment of the beef production system may have unrealized impacts on herd profitability.

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Table 3. Effects of late gestation nutrition[1] on May-calving dam BW, BCS, and reproductive and calf performance

	M		R			*P*-value[2]		
	NS	S	NS	S	SEM	Graze	Supp	G × S
n	181	163	148	159				
Cow BW, lb								
Initial	926	928	935	930	9	0.62	0.87	0.75
Prepartum	1,027	1,045	983	1,021	9	< 0.01	< 0.01	0.25
BW change, lb	99^{ab}	115^{a}	51^{c}	93^{b}	6	< 0.01	< 0.01	0.02
Cow BCS[3]								
Initial	4.6	4.5	4.6	4.6	0.04	0.61	0.10	0.35
Prepartum	4.6	4.7	4.6	4.8	0.05	0.78	< 0.01	0.45
BCS change	0.0	0.2	0.0	0.2	0.04	0.58	< 0.01	0.94
Dystocia, %[4]	0	1	1	0	1	0.96	0.95	0.15
Pregnancy rate, %	90	89	82	87	3	0.08	0.48	0.37
Calf BW, lb								
Birth	73	75	71	73	1	0.07	0.04	0.84
Pre-breed	216^{ab}	216^{ab}	207^{b}	234^{a}	9	0.58	0.11	0.09
Weaning	439	445	430	443	4	0.09	0.02	0.33

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

[1] May-calving dams were arranged in a 2 × 2 factorial at weaning in January and were assigned to 1 of 2 forage types: sub-irrigated meadow (M) or upland range (R) for 116 d and then to 1 of 2 supplementation groups: 1 lb/d of 33% CP (DM) supplement (S) or no supplement (NS) for 85 d.

[2] Graze = grazing treatment, Supp = supplementation treatment, and G × S = grazing and supplement assignment interaction.

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

[4] At parturition a calving ease (CE) score was assigned (1 = no assistance to 4 = caesarian section). A score of 2 or greater was considered dystocia.

Effects of Maternal Late Gestation Nutrition on May-Born Heifer Progeny

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Summary with Implications

May-calving dams in late gestation grazed either sub-irrigated meadow with or without supplement or upland range with or without supplement. Supplementation was 1 lb/d of a 33% CP (DM) supplement. Heifer progeny from these dams were followed through their first and second breeding seasons. Both dam grazing and supplement treatment affected heifer progeny BW and BCS. Heifers born to dams who grazed meadow in late gestation attained a greater percentage of mature BW at the start of their first breeding season and increased pregnancy rates as primiparous cows. Grazing of meadow by May-calving dams in late gestation may increase stayability of heifer progeny. Although supplementing the dam during late gestation tended to increase heifer progeny BW at first breeding, the increased risk of dystocia at heifer's first parturition may negate the benefit.

Table 1. Predicted[1] composition of diets offered to May-calving dams in late gestation[2]

	Meadow		Range	
	NS	S	NS	S
January				
CP, % mid-gestation req.[3]	85.9	95.8	70.4	80.3
NEm, % mid-gestation req.[4]	96.9	99.0	118.4	120.4
February				
CP, % late gestation req.[5]	139.2	146.8	73.8	82.3
NEm, % late gestation req.[6]	76.4	79.1	104.5	106.4
March				
CP, % late gestation req.	251.9	255.7	153.2	159.5
NEm, % late gestation req.	143.6	143.6	143.6	143.6
April				
CP, % late gestation req.	320.7	322.8	160.3	167.1
NEm, % late gestation req.	144.5	144.5	156.4	156.4

[1] Diet composition predicted using a computer model based on NRC, 2000 equations.

[2] May-calving dams were arranged in a 2 × 2 factorial at weaning in January and were assigned to 1 of 2 grazing treatments: sub-irrigated meadow (M) or upland range (R) for 116 d and then to 1 of 2 supplementation treatments: 1 lb/d of 33% CP (DM) supplement (S) or no supplement (NS) for 85 d.

[3] CP expressed as a percentage of requirement for mid-gestation multiparous dams (7.1% CP, DM; NRC, 2000).

[4] NEm expressed as a percentage of the requirement for mid-gestation multiparous dams (0.45 Mcal/lb; NRC, 2000).

[5] CP expressed as a percentage of requirement for late gestation multiparous dams (7.9% CP, DM; NRC, 2000).

[6] NEm expressed as a percentage of the requirement for late gestation multiparous dams (0.50 Mcal/lb; NRC, 2000).

Introduction

Late gestation for a May-calving herd occurs during early grass growth, which allows forage CP and TDN to meet or exceed dam requirements. Rapid growth of the fetus occurs in late gestation and is particularly sensitive to imbalances in maternal nutrition. Data examining maternal overconsumption of protein on progeny postnatal development is limited and largely inconclusive. Differences in forage species and consequent protein and energy levels can affect heifer progeny postnatal growth and reproductive performance. Previous research (*2006 Nebraska Beef Cattle Report*, pp. 10–12) with March-born heifer progeny demonstrated increased pregnancy rates if their dam was protein supplemented in late gestation. This may have been a result of increasing dam dietary protein to adequate levels, as forage is dormant during late gestation of a March-calving herd. Early research (*2018 Nebraska Beef Cattle Report*, pp. 24–27) on this study indicated May-born heifer progeny whose dams grazed upland range without supplement tended to have decreased birth and weaning BW. The objective of the current study was to evaluate the effect of maternal grazing system and supplementation on heifer progeny through their first and second breeding seasons, as well as heifer progeny's first calf BW.

Procedure

Dam Management

Dam management has been reported in detail (*2019 Nebraska Beef Cattle Report*, pp. 9–11). For 6 years, dams were arranged in a 2 × 2 factorial on approximately d 160 of gestation. Dams were assigned to graze either upland range (R) or sub-irrigated meadow (M), and then assigned to receive either no supplement (NS) or 1 lb/d (S) of a 33% CP (DM) supplement. Grazing treatment continued for approximately 116 ± 2 d (mean ± SD) while supplementation treatment continued for approximately 85 ± 2 d (mean ± SD). Predicted dietary CP and TDN values are presented in Table 1 for each treatment combination. Dams were managed as a single herd the remainder of the year.

Heifer Progeny Management

Heifers (n = 310) were weaned at 8 mo of age and assigned to 1 of 2 development treatments from January to May (*2018 Nebraska Beef Cattle Report*, pp. 24–27). At 14 mo of age, heifers entered their first breeding season. On d-10 and 0 of the breeding season, blood samples (5 mL)

Table 2. Effect of late gestation nutrition on May-born heifer progeny BW, BCS, and reproductive performance

	M		R			*P*-value[2]		
	NS	S	NS	S	SEM	Graze	Supp	G × S
n	81	76	74	79				
Heifer BW, lb								
Prebreeding (14 mo)	701	701	694	694	4	0.20	0.92	0.94
Pregnancy diagnosis (17 mo)	791	789	785	785	4	0.37	0.85	0.75
Prepartum (23 mo)	842	851	858	869	11	0.13	0.41	0.94
Prebreeding (26 mo)	873	882	884	875	9	0.78	0.96	0.31
Pregnancy diagnosis (30 mo)	864	895	891	904	13	0.13	0.06	0.42
Heifer BCS[3]								
Pregnancy diagnosis (17 mo)	5.9	5.9	5.8	5.8	0.03	0.13	0.40	0.74
Prepartum (23 mo)	5.2	5.1	5.1	5.0	0.06	0.24	0.19	0.66
Prebreeding (26 mo)	5.4^{ab}	5.5^{a}	5.4^{ab}	5.2^{b}	0.07	0.02	0.38	0.04
Pregnancy diagnosis (30 mo)	5.2^{b}	5.5^{a}	5.3^{ab}	5.3^{ab}	0.08	0.76	0.08	0.01
Pubertal, %[4]	71	79	76	68	5	0.62	0.97	0.12
Percent mature BW, %[5]	60	61	58	59	0.7	0.01	0.06	0.59
Heifer pregnancy rate, %	78	79	72	74	5	0.29	0.81	0.88
Dystocia, %[6]	10	17	8	28	7	0.54	0.02	0.35
PPI, d[7]	89	89	96	95	3	0.03	0.99	0.83
Primiparous cow pregnancy rate, %	84	93	74	74	8	0.02	0.35	0.36

[1] May-calving dams were arranged in a 2 × 2 factorial at weaning in January and were assigned to 1 of 2 forage types: sub-irrigated meadow (M) or upland range (R) for 116 d and then to 1 of 2 supplementation groups: 1 lb/d of 33% CP (DM) supplement (S) or no supplement (NS) for 85 d.

[2] Graze = grazing treatment, Supp = supplementation treatment, and G × S = grazing and supplement interaction.

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

[4] Considered pubertal if blood serum progesterone concentration > 1 ng/ml.

[5] Percent of mature BW at 14 mo of age. Calculated using a May-herd mature cow BW of 1,172 lb.

[6] At parturition a calving ease (CE) score was assigned (1 = no assistance to 4 = caesarian section). A score of 2 or greater was considered as dystocia.

[7] PPI = postpartum interval. Conception date was calculated by subtracting 285 d from subsequent calving date.

were collected from heifers via coccygeal venipuncture to determine plasma progesterone concentrations. Heifers were considered pubertal if plasma progesterone concentrations were ≥ 1.0 ng/mL at one or both time points. Heifer BW was recorded at blood collection and prebreeding BW was considered the average of these 2 time points. Heifer progeny were placed with fertile bulls at a 1:20 bull to heifer ratio for a 45 d breeding season. Heifers were synchronized using a single $PGF_{2\alpha}$ (5 mL i.m., Lutalyse; Zoetis Animal Health, Parisippany, NJ) 5 d after bull placement. Body weight and BCS were recorded and pregnancy diagnosed via transrectal ultrasonography in mid-October. Two weeks prior to calving, heifer BW and BCS was recorded. A calving ease (CE) score (1 = no assistance, 2 = easy assist, 3 = difficult assist, and 4 = caesarian section) was assigned at parturition, with scores of 2 or greater considered dystocia. Body weight and BCS were recorded at the start of the subsequent breeding season. Pregnancy status was diagnosed in November via transrectal ultrasonography, and BW and BCS recorded. Calves were weaned from heifers at this time.

Heifer Progeny First Calf Management

The BW of the first calf born to heifer progeny was analyzed based on granddam pasture and supplement treatment. At parturition, calf birth BW, sex, and birth date were recorded. Calves were vaccinated and male calves castrated at prebreeding. Calf BW was recorded at prebreeding in July and weaning in November.

Statistical Analysis

All data were analyzed using the PROC GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC, version 9.4). The model statement included the fixed effects of dam grazing treatment, supplementation treatment, and the resulting interaction. The experimental unit was considered dam treatment × year, where dam treatment consisted of the grazing system, supplementation treatment, and the interaction. Dam age and year were included as a covariate in all analyses. The sex of the heifer progeny's first calf was included as a covariate when analyzing heifer parturition data and their calf BW. Covariates were removed from the model statement when $P > 0.05$. Data were considered significant at $P \leq 0.05$ and a tendency if $P \leq 0.10$ and $P > 0.05$.

Results

Heifer Progeny Performance

Heifer progeny BW, BCS, and reproductive performance are presented in Table 2. Neither prebreeding BW nor percentage of heifers pubertal at the start of the breeding

Table 3. Effect of grand-dam late gestation nutrition[1] on May-born calf BW

	M		R			*P*-value[2]		
	NS	S	NS	S	SEM	Graze	Supp	G × S
n	44	45	40	46				
Birth	64	66	64	66	2	0.38	0.08	0.86
2 mo	194	192	194	198	4	0.21	0.74	0.19
Wean (6 mo)	351	359	353	366	9	0.59	0.17	0.80

[1] May-calving grand-dams were arranged in a 2 × 2 factorial at weaning in January and were assigned to 1 of 2 grazing treatments: sub-irrigated meadow (**M**) or upland range (**R**) for 116 d and then to 1 of 2 supplementation treatments: 1 lb/d of 33% CP (DM) supplement (**S**) or no supplement (**NS**) for 85 d.

[2] Graze = grazing treatment, Supp = supplementation treatment, and G × S = grazing and supplement interaction.

season were affected ($P \geq 0.12$) by dam treatment. Conversely, heifers born to supplemented dams tended ($P = 0.06$) to attain a higher percentage of mature BW at the start of the breeding season (60 vs. 59 ± 0.5%, S vs. NS). Furthermore, heifers whose dams grazed meadow in late gestation also had increased ($P = 0.01$) percentage of mature BW attained by start of their first breeding season (60 vs. 59 ± 0.5%, M vs. R). In late gestation, the bovine fetus is undergoing hypertrophy of muscle fibers and hyperplasia of adipocyte tissue. Both meadow grazing and supplementation of the dam resulted in an increased percentage of mature BW attained at start of the heifer's first breeding season, suggesting these treatments may have altered development of muscle or adipose tissue. In this study, there does not appear to be a correlation between percentage of mature BW attained by the start of their first breeding season and pubertal attainment ($r^2 = 0.04$). Leptin, a key regulator in pubertal attainment, has been shown to be altered by developmental programming, and may have affected pubertal attainment. Although leptin was not measured in the current study, it is possible leptin concentrations were altered by dam treatments and further research is warranted.

At pregnancy diagnosis in mid-October, heifers had a similar ($P \geq 0.13$) BW and BCS. Heifer pregnancy rate was also similar ($P \geq 0.29$) among dam treatments, in contrast to what Martin et al. (*2006 Nebraska Beef Cattle Report*, pp. 10–12) observed with March-born heifer progeny born to protein-supplemented dams. Prepartum BW and BCS were also similar ($P \geq 0.13$). At calving, dystocia was increased ($P = 0.02$) for heifers if their dams were supplemented in late gestation (9 vs. 20 ± 5%, NS vs. S); however, dam grazing treatment had no effect ($P = 0.54$).

At the beginning of the subsequent breeding season, heifer BW was not different ($P \geq 0.10$) between treatments; however, there was a pasture × supplement interaction ($P = 0.04$) for BCS. Second prebreeding BCS was greatest for heifers born to MS dams, intermediate for MNS and RNS, and least for RS. Late gestation maternal treatments may have altered fetal tissue development, leading to differences in apparent fatness of heifer progeny. Postpartum interval was decreased ($P = 0.03$) in heifers whose dams grazed meadow (89 vs. 95 ± 2 d, M vs. R), while supplementation had no effect ($P = 0.99$). At second pregnancy diagnosis in November, dam supplementation tended ($P = 0.06$) to increase heifer BW (899 vs. 877 ± 7 lb, S vs. NS). Furthermore, a grazing × supplement interaction ($P = 0.01$) was detected for heifer BCS at second pregnancy diagnosis, with MS again having the highest BCS, RNS and RS intermediate, and MNS lowest. Additionally, the percentage of primiparous cows diagnosed pregnant with their second calf was increased ($P = 0.02$) if their dam grazed meadow in late gestation (91 vs. 76 ± 5%, M vs. R).

Previous work with developmental programming has suggested differences in late gestation maternal nutrition may alter progeny postnatal muscle or adipose cell growth and proliferation. This may explain the differences in heifer progeny BW and BCS, particularly during prebreeding and pregnancy diagnosis as a primiparous cow. Furthermore, heifers whose dams grazed meadow in late gestation had a decreased PPI and increased rebreed pregnancy rates as primiparous cows. Throughout all of these physiological processes, regulation of the hypothalamic-pituitary-gonadal axis is key. Leptin is a key mediator in all these processes, as well as in conceptus implantation.

Performance of Heifer Progeny First Calf

First calf BW from heifer progeny is presented in Table 3. Grand dam grazing treatment did not affect ($P \geq 0.21$) calf BW at birth, prebreeding, or wean. Alternately, grand dam supplementation treatment tended ($P = 0.08$) to increase calf birth BW (66 vs. 64 ± 2 lb, S vs. NS), but did not affect ($P \geq 0.17$) any other measurement. This may have contributed to the calving difficulties previously described.

Conclusions

Dams who grazed meadow in late gestation gave birth to heifer progeny who attained an increased percentage of mature BW by their first breeding season, decreased PPI, and increased pregnancy rates as primiparous cows. Dam supplementation in late gestation resulted in heifer progeny who gave birth to heavier calves and experienced increased dystocia rates. Although the level of dietary CP offered to the dam found in this study is unlikely in confined operations fed a constant ration, forage-based operations have little control over plant growth. Differences in forage growth during gestation may have long-term implications for the beef cattle production system.

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Effects of Maternal Late Gestation Nutrition on May-Born Steer Progeny

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Summary with Implications

May-calving dams were assigned to graze either sub-irrigated meadow or upland range with or without supplementation (1 lb/d 33% CP). Treatment began at approximately 160 d of gestation. Supplementation continued for 85 ± 2 d, while grazing system treatment continued for 116 ± 2 d. Steer progeny were backgrounded after weaning and then assigned to either a short or long yearling feedlot system. Dam supplementation tended to decrease marbling score within both feedlot systems. Short yearling steers had an increased percentage of carcasses grade USDA low Choice or greater if their dams grazed meadow in late gestation. Long yearling steers had increased carcass weight if their dams grazed meadow. Increased profitability of steer progeny carcasses may be realized if May-calving dams are allowed to graze meadow in late gestation.

Introduction

Current research suggests imbalances in maternal nutrition during gestation can affect progeny growth and performance long-term. Previous research (*2009 Nebraska Beef Cattle Report*, pp. 5–8) with March-born steer progeny born to late gestation protein-supplemented dams have increased weaning BW, hot carcass weight (HCW), and percentage of steers grading USDA Choice or greater. Late gestation for a March-herd occurs overwinter, when grasses are dormant and dietary CP is below dam requirements. Conversely, late gestation May-calving dams may experience excess dietary CP when grazing, due to early grass growth (*2019 Nebraska Beef Cattle Report*, pp. 9–11). These differences in forage ontogeny between the 2 calving systems may result in differences in available nutrients to the fetus and cause long-term implications for progeny. The objective of this study was to evaluate the effect of maternal grazing system with and without supplementation on May-born steer progeny assigned to 2 feedlot systems.

Procedure

Dam Management

A 6 yr study was conducted at the Gudmundsen Sandhills Laboratory (GSL), Whitman, to examine the effects of dam grazing system with and without supplementation on steer progeny. Dam management has been reported in detail (*2019 Nebraska Beef Cattle Report*, pp. 9–11). Dams were arranged in a 2 × 2 factorial on approximately d 160 of gestation. Dams grazed either upland range (R) or sub-irrigated meadow (M), and then received either no supplement (NS) or 1 lb/d (S) of a 33% CP (DM) dried distillers grains-based supplement. Grazing treatment continued for approximately 116 ± 2 d (mean ± SD) while supplementation treatment continued for approximately 85 ± 2 d (mean ± SD). Dams were managed as a single herd the remainder of the year.

Steer Progeny Management

Steers were vaccinated and castrated at 2 mo of age. At weaning in January, steers were assigned to 1 of 2 backgrounding treatments (*2019 Nebraska Beef Cattle Report*, pp. 32–35). In May, one-half of the steers from each backgrounding treatment were transported to the feedlot at the West Central Research and Extension Center (WCREC), North Platte, (short-yearling, n = 195) and implanted with Synovex Choice (Ft. Dodge Animal Health, Overland Park, KS). The steers remaining at GSL (long-yearling, n = 197) were implanted with Revalor G (Merck Animal Health, Summit, NJ) and grazed upland range for 90 d. Approximately Sept. 14, long-yearling steers were transported to the feedlot and implanted with Ralgro (Merck Animal Health). Upon feedlot entry, both groups of steers were limit fed 5 d at 2.0% of BW and weighed 3 consecutive d. Feedlot entry BW was the average of these 3 time points. Steers were transitioned over 21 d to a common diet containing 48% dry rolled corn, 40% wet corn gluten feed, 7% prairie hay, and 5% supplement (DM basis). The supplement included vitamins, minerals, monensin (1.3 g/lb; Rumensin, Elanco Animal Health, Indianapolis, IN), and tylosin (1.0 g/lb; Tylan 40, Elanco Animal Health). Steers were placed in a GrowSafe feeding system approximately 2 wk after feedlot entry. No intake data were recorded over the initial 2-wk adaptation period to the system. Recorded intakes from the GrowSafe system were used to calculate DMI and F:G. Approximately 110 d after feedlot entry for short-yearling steers and 70 d for long-yearlings steers, BW was measured and steers re-implanted with Synovex Plus (Ft. Dodge Animal Health). Steers were slaughtered 97 d after reimplant for short-yearlings steers and 95 d for long-yearlings steers. Hot carcass weight was recorded at slaughter and carcass data were collected following a 24-h carcass chill. Final BW was calculated by adjusting HCW to a common dressing percentage of 63%.

Statistical Analysis

All data were analyzed using the PROC GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC, version 9.4). The model statement included the fixed effects of dam grazing treatment, supplementation treatment, and the resulting interaction. The experimental unit was considered as dam treatment × feedlot system × year, where dam treatment was either dam grazing system or supplement. Dam age and yr were included as a covariate in all analyses and were removed when $P > 0.05$. Significant

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Table 1. Effect of late gestation nutrition[1] on May-born short-yearling steer[2] feedlot BW, ADG, DMI, performance, and carcass characteristics

	M		R			P–value[3]		
	NS	S	NS	S	SEM	Graze	Supp	G × S
n	35	27	25	34				
Feedlot entry BW, lb	593	569	580	573	6	0.76	0.17	0.45
Final live BW, lb[4]	1,424	1,413	1,376	1,411	11	0.26	0.61	0.31
ADG, lb	3.90	3.97	3.73	3.90	0.09	0.13	0.17	0.53
DMI, lb	26.7^{a}	26.0^{ab}	24.9^{b}	26.2^{ab}	0.4	0.08	0.41	0.05
DMI, % BW	2.6	2.7	2.6	2.6	0.04	0.28	0.26	0.63
F:G, lb:lb	6.7	6.7	6.7	6.7	0.4	0.71	0.45	0.39
Carcass								
HCW, lb	897	891	866	888	15	0.26	0.61	0.31
Marbling score[5]	483	445	443	430	15	0.04	0.06	0.37
12th rib fat, in	0.63	0.65	0.60	0.58	0.04	0.11	0.96	0.47
LMA[6], in^{2}	14.8^{x}	14.5^{xy}	14.3^{y}	14.9^{x}	0.3	0.71	0.54	0.08
Yield grade	3.2	3.4	3.3	3.1	0.1	0.40	0.83	0.14
Choice^{-} or greater, %	93	75	69	68	9	0.03	0.13	0.15
Choice^{0} or greater, %	28	20	25	14	10	0.54	0.27	0.79

^{a,b}Means within a row lacking a common superscript differ ($P \leq 0.05$).

^{x,y}Means within a row lacking a common superscript tend to differ ($P \leq 0.10$).

[1] May-calving dams were arranged in a 2 × 2 factorial at weaning in January and were assigned to 1 of 2 grazing treatments: sub-irrigated meadow (M) or upland range (R) for 116 d and then to 1 of 2 supplementation treatments: 1 lb/d of 33% CP (DM) supplement (S) or no supplement (NS) for 85 d.

[2] Following backgrounding, short-yearling steers entered the feedlot immediately in May.

[3] Graze = grazing treatment, Supp = supplementation treatment, and G × S = grazing and supplement assignment interaction.

[4] Final BW calculated from HCW adjusted to a common dressing percent of 63%.

[5] 300 = slight^{00}, 350 = slight^{50}, 400 = small^{00}, 450 = small^{50}, 500 = modest^{00}.

[6] LMA = *Longissimus* muscle area.

interactions were detected between feedlot system and dam grazing and supplement treatment, so data are presented by feedlot system. Data were considered significant at $P \leq 0.05$ and a tendency if $P \leq 0.10$ and $P > 0.05$.

Results

Short-Yearling Steer Progeny Feedlot Performance and Carcass Characteristics

Feedlot BW, ADG, performance, and carcass characteristics of short-yearling steers are presented in Table 1. Feedlot entry and final BW were similar ($P \geq 0.17$) between dam treatments. Correspondingly, ADG was not affected ($P \geq 0.13$) by treatment. There was a pasture × supplement interaction ($P = 0.05$) for DMI, with MNS consuming the greatest amount of feed, RS and MS intermediate, and RNS the least. Despite this, DMI expressed as a percentage of BW and F:G were similar ($P \geq 0.20$) among treatments.

In agreement with final BW, HCW at slaughter were similar ($P \geq 0.26$). Marbling scores were increased ($P = 0.04$) in steers whose dams grazed meadow (464 vs. 436 ± 10, M vs. R), while dam supplementation tended ($P = 0.06$) to decrease marbling scores (463 vs. 438 ± 10, NS vs. S). This contrasts with Stalker et al. (*2006 Nebraska Beef Cattle Report*, pp. 7–9), who observed March-born steers born to supplemented dams had increased marbling scores. Protein supplementation of a March-calving dam may have increased dietary CP and TDN to adequate levels, while protein supplementation of a May-calving dam may have resulted in an even greater excess dietary CP and TDN. Additionally, more ($P = 0.03$) steers graded Choice^{-} or greater if their dams grazed meadow in late gestation (85 vs. 69 ± 8%, M vs. R). Dam treatment did not affect ($P \geq 0.11$) percentage of steers grading Choice^{0} or greater or steer progeny 12th rib fat thickness. There was a tendency ($P = 0.08$) for a grazing × supplement interaction for *longissimus* muscle area (LMA), with RS and MNS steers having the greatest area, MS intermediate, and RNS least. Despite this tendency, yield grades were similar ($P \geq 0.14$).

Long-Yearling Steer Progeny Feedlot Performance and Carcass Characteristics

Feedlot phase BW, ADG, performance, and carcass characteristics for long-yearling steers are presented in Table 2. Similar to short-yearling steers, feedlot entry BW was not affected ($P \geq 0.16$) by dam treatment; however, final BW tended ($P = 0.10$) to be greater for steers born to dams grazing meadow in late gestation (1,517 vs. 1,475 lb ± 17, M vs. R). Despite this, no differences ($P \geq 0.26$) were detected in ADG. Feedlot DMI was increased ($P = 0.01$) if dams grazed meadow (29.4 vs. 28.0 ± 0.4 lb/d, M vs. R), but dam supplementation did not affect ($P = 0.95$) DMI. When DMI was expressed as a percentage of BW, there was a tendency ($P = 0.09$) for a pasture × supplement interaction where steers born to MS dams had the greatest DMI as % BW, MNS and RNS were intermediate, and RS

Table 2. Effect of late gestation nutrition[1] on May-born long-yearling steer[2] feedlot BW, ADG, DMI, performance, and carcass characteristics

	M		R			P–value[3]		
	NS	S	NS	S	SEM	Graze	Supp	G × S
n	35	37	26	33				
Feedlot entry BW, lb	802	796	774	807	7	0.56	0.30	0.16
Final live BW, lb[4]	1,536	1,495	1,461	1,490	13	0.10	0.82	0.18
ADG, lb	4.25	4.01	4.03	3.97		0.31	0.26	0.53
DMI, lb	29.5	29.3	27.8	27.8	0.7	0.01	0.95	0.93
DMI, % BW	2.5^{xy}	2.6^{x}	2.5^{xy}	2.4^{y}	0.04	0.05	0.78	0.09
F:G, lb:lb	6.7	7.1	7.1	7.1	0.2	0.91	0.57	0.17
Carcass								
HCW, lb	968	944	922	939	18	0.10	0.82	0.18
Marbling score[5]	502	496	509	463	17	0.39	0.09	0.18
12th rib fat, in	0.64	0.61	0.64	0.64	0.04	0.76	0.77	0.64
LMA[6], in^2	15.1	14.6	14.8	14.8	0.3	0.64	0.18	0.60
Yield grade	3.4	3.4	3.3	3.5	0.2	0.88	0.56	0.63
Choice$^-$ or greater, %	91	82	81	78	5	0.12	0.16	0.44
Choice^0 or greater, %	40	48	48	26	11	0.48	0.44	0.14

[x,y] Means within a row lacking a common superscript tend to differ ($P \leq 0.10$).

[1] May-calving dams were arranged in a 2 × 2 factorial at weaning in January and were assigned to 1 of 2 grazing treatments: sub-irrigated meadow (M) or upland range (R) for 116 d and then to 1 of 2 supplementation treatments: 1 lb/d of 33% CP (DM) supplement (S) or no supplement (NS) for 85 d.

[2] Following backgrounding, long yearling steers grazed upland range for 90 d before entering the feedlot in mid-September.

[3] Graze = grazing treatment, S = supplementation treatment, and G × S = grazing and supplement assignment interaction.

[4] Final BW calculated from HCW adjusted to a common dressing percent of 63%.

[5] 300 = slight^{00}, 350 = slight^{50}, 400 = small^{00}, 450 = small^{50}, 500 = modest^{00}.

[6] LMA = *Longissimus* muscle area.

the least. Conversely, F:G was similar ($P \geq 0.17$) between treatments despite differences in DMI.

In agreement with final BW, HCW tended ($P = 0.10$) to be greater for steers born to dams grazing meadow (954 vs. 930 ± 11 kg, M vs. R). Similar to short-yearling steers, marbling score had a tendency ($P = 0.09$) to be decreased by dam supplementation (506 vs. 480 ± 11, S vs. NS), but no difference ($P = 0.39$) was detected due to dam grazing treatment. There were no differences ($P \geq 0.12$) in the percentage of steers grading Choice$^-$ or Choice^0 or greater. Neither 12th rib fat thickness nor LMA were different ($P \geq 0.18$) between treatments. Yield grade was also similar ($P \geq 0.56$) between dam treatments.

Conclusions

Dry matter intake was increased for steer progeny in both feedlot systems if their dams grazed meadow in late gestation. Additionally, marbling score of steer progeny within both feedlot systems tended to be decreased if dams were supplemented. Steer progeny in a long-yearling feedlot system tended to have increased HCW if their dams grazed meadow in late gestation, while maternal meadow grazing resulted in an increased percentage of short-yearling steers grading USDA low Choice or greater. Differences in maternal nutrition resulted in differences in feedlot and carcass performance of steer progeny. Grazing May-calving dams on sub-irrigated meadow in late gestation may result in increased carcass value of steer progeny.

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Impact of Cow Size on Cow-Calf and Subsequent Steer Feedlot Performance

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Summary with Implications

This study retrospectively evaluated the effect of cow size on cow-calf performance and post-weaning steer feedlot performance of cows at the Gudmundsen Sandhills Laboratory, Whitman. Cows were categorized at small, medium, or moderate within cow age from 13 years of data. Small cows had decreased reproductive performance, weaned smaller calves, and produced steer progeny with smaller carcass weights. In this dataset and under the environmental and management conditions at Gudmundsen Sandhills Laboratory, overall productivity of the cowherd decreased as cow size decreased with 1,150 to 1,200 lb cow being the most productive cow size.

Introduction

Optimizing cow herd production efficiency is a combination of feed inputs and output. In doing so, ranch efficiency requires an understanding and managing for genetic potential (i.e., cow size, milk production) and how it fits within the given environment and environmental constraints. Mature cow size of the herd has long been debated on what the optimal cow size for a given environment is. Cow size has traditionally been utilized in selecting cows to fit their environmental conditions. Cow size studies; however, are often limited in duration and size, done as simulation studies, or usually end at weaning. In semi-arid and limited resource environments, small to moderate size cows have been suggested to be more efficient than and as productive as larger cows. However, within environments, there may be a limitation where selection for moderation in the cow herd may limit overall production. Therefore, the objectives of this study was to retrospectively analyze cow size data to determine the effects cow size in the Nebraska Sandhills on cow performance, calf performance, and post-weaning performance of feedlot steers.

Procedure

The University of Nebraska–Lincoln Institutional Animal Care and Use Committee approved all procedures used in this experiment. Cow performance data were collected from 2005 to 2017 at the Gudmundsen Sandhills Laboratory (Whitman, NE) from March (n = 3,448) and May (n = 934) calving herds.

Cows utilized in this study were Husker Red (5/8 Red Angus, 3/8 Simmental) and ranged from 2 to 11 yr of age. To correct for differences in BCS at weaning, cow body weight at weaning was adjusted to a common body condition score of 5. Cow size groups were then determine by taking the average adjusted BW within each age and stratifying to groups as small (< 1 standard deviation from mean within age), medium (within 1 standard deviation from mean with age), or moderate (> 1 standard deviation from mean with age). Grouping cow size within age was conducted to normalize data within age of cows so that younger cows would not automatically fall into small cow size and confound results by cow age. Cow size treatment groups were stratified within age to eliminate young cows not yet at mature BW from being miscategorized into the small category. In addition, young cows were left in the dataset to determine if cow age interacts with cow size on productivity. Cow BW at weaning ranged from 642 to 1745 lb with only 3% of cows over 1250 lb at weaning over the years.

Over the years, calf management varied slightly depending on research. In general, calves were vaccinated at 2 mo of age with an infectious bovine rhinotracheitis, parainfluenza-3 virus, bovine respiratory syncytial virus, and bovine viral diarrhea type I and II vaccine (BoviShield 5, Zoetis, Florham Park, NJ). Calves were also weighed, branded, and male calves were castrated. Cow-calf pairs then grazed native upland range pastures. At weaning, calves were weighed and vaccinated against bovine rotavirus-coronavirus clostridium perfringens types C and D and *Escherichia* (Bovine Rota-Coronavirus Vaccine, Zoetis, Florham Park, NJ). After weaning, March-born steer calves (n = 1,186) were placed in a drylot and consumed ad libitum hay for 2 weeks post-weaning after which they were transported to West Central Research and Extension Center (WCREC), North Platte. After weaning, May-born steers (n = 386) grazed subirrigated meadow with 1 lb of supplement or received ad libitum hay with 4 lb of supplement until approximately 1 yr of age then relocated to WCREC.

At feedlot entry, all steer calves were implanted with 14 mg estradiol benzoate and 100 mg trenbolone acetate (Synovex Choice, Zoetis) and transitioned over 21 d to a common finishing diet of 48% dry rolled corn, 40% corn gluten feed, 7% prairie hay, and 5% supplement. From 2005 to 2010, steers were pen fed for the finishing period after the arrival at WCREC. Starting in 2011, steers were placed in a GrowSafe feeding system (GrowSafe Systems Ltd., Airdrie, Alberta, Canada) approximately 2 wk after arrival at WCREC. All steer BW was measured on 2 consecutive days before feedlot entry. In addition, from 2011 to 2017, steers were weighed again 10 d after acclimating to the GrowSafe feeding system. The average of the 2-d BW following acclimation was considered the initial feedlot entry BW used in measuring feedlot performance (BW change, DMI, and ADG) was calculated from the average BW. Approximately 100 d before slaughter, calves were implanted with 28 mg estradiol benzoate and 200 mg trenbolone acetate (Synovex Plus, Zoetis). March-born steer calves were managed similarly during finishing as the May-born calves; however, steer calves were fed as a group in drylot pens. Each year, steers were slaughtered at

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Table 1. Effect of cow size on cow-calf performance in the Nebraska Sandhills

	Cow Size[1]				
Measurement	Small	Medium	Moderate	SEM	*P*-value
Cow BW, lb					
Calving	961^{a}	$1{,}080^{b}$	$1{,}187^{c}$	6	< 0.01
Breeding	947^{a}	$1{,}065^{b}$	$1{,}178^{c}$	6	< 0.01
Weaning	882^{a}	$1{,}025^{b}$	$1{,}187^{c}$	5	< 0.01
Cow BW change, lb					
Calving to weaning	-72^{a}	-54^{b}	0^{c}	5	< 0.01
Cow BCS[2]					
Calving	4.8^{a}	5.1^{b}	5.3^{c}	0.06	< 0.01
Breeding	5.2^{a}	5.4^{b}	5.6^{c}	0.02	< 0.01
Weaning	4.9^{a}	5.1^{b}	5.2^{c}	0.03	< 0.01
Pregnancy rate, %	86^{a}	92^{b}	97^{c}	3	< 0.01
Calf BW, lb					
Birth	72^{a}	76^{b}	79^{c}	0.6	< 0.01
Breeding	226^{a}	235^{b}	240^{c}	2	< 0.01
Weaning	460^{a}	483^{b}	498^{c}	3	< 0.01
205-d	425^{a}	452^{b}	474^{c}	3	< 0.01
Cow size weaned[3], %	52.5^{a}	47.7^{b}	42.9^{c}	0.4	< 0.01
Calf ADG, lb/d					
Birth to breeding	2.03^{a}	2.12^{b}	2.13^{b}	0.02	< 0.01
Birth to weaning	1.78^{a}	1.87^{b}	1.94^{c}	0.01	< 0.01

[abc] Within a row, means with differing superscript letter differ ($P < 0.05$).

[1] Cow size determined by adjusting cow BW at weaning to a BCS 5.

[2] Scale of 1 (emaciated) to 9 (extremely obese).

[3] Calculated by dividing calf weaning BW by dam weaning BW.

a commercial facility (Tyson Fresh Meats, Lexington, NE) when estimated visually to have 0.5 in fat thickness over the 12th rib. Carcass data were collected 24 h post slaughter and final BW was calculated from hot carcass weight (HCW) based on average dressing percentage of 63%.

Data were analyzed using the PROC MIXED and GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC). Models included the effect of cow size, cow age, calving season, and calf sex for all appropriate data. Cow age was used as a blocking term. Data are presented as LSMEANS and *P-v*alues ≤ 0.05 were considered significant and tendencies were considered at a $P > 0.05$ and $P \leq 0.10$.

Results

Cow Performance Results

Cow BW at pre-calving, breeding, and weaning were greater as cow size increase ($P < 0.01$; Table 1), expected due to the experimental design. Moderate cows maintained BW from calving to weaning; whereas, small and medium sized cows lost BW ($P < 0.01$). In addition, BCS was lower ($P < 0.01$, Table 2) for small-sized cows at pre-calving, pre-breeding, and weaning. Pregnancy rates increased with increasing cow size ($P < 0.01$) with the lowest pregnancy rates in small cows. The increase in BW loss and decrease in pregnancy rate in small-sized beef cows may be due to an imbalance of genetic potential for milk production and ability to consume enough forage to support that milk production level. Although milk production level will increase forage intake, cow size will have larger impact on forage intake. Therefore, milk production in the small-sized cows may have been too great for the nutritional environment of the Sandhills, resulting in greater BW loss and decreased reproductive performance.

Calf BW at birth, breeding, weaning, and 205-d weight increased ($P < 0.01$, Table 1) as cow size increased. Calf ADG from birth to breeding was lower ($P < 0.01$) in calves from small-sized dams, where offspring from medium- and moderate-sized cows having similar ADG to breeding. Overall ADG from birth to weaning was greater ($P < 0.01$) in calves from moderate-sized cows. Although, as a percent of cow size, small-sized beef cows did wean a greater ($P < 0.01$) percentage of their BW compared with their larger counterparts, which is expected. In general, small cows tend to be more efficient at weaning a larger percentage of their BW than larger cows.

Post-weaning Steer Performance

Steer feedlot entry BW increased ($P < 0.02$, Table 2) as dam size increased. Steer BW at reimplant tended ($P = 0.07$) to increase with increased dam size. In addition, final BW was greater ($P < 0.01$) for steer from moderate cows with no difference in finishing BW between steers from small and medium cows. Although finishing steer BW were lighter from smaller cows, small cows did have steers with a finishing feedlot BW approximately 1.5 times their mature BW. Feedlot ADG, DMI, and G:F were not different ($P \geq 0.52$) among steers from dams with increasing cow size. Similar to final BW, HCW increased ($P < 0.01$) in steers from moderate dams with no difference between steers from small and medium cows. Marbling score and yield grade were not different ($P > 0.39$) regardless of dam size. However, LM area and back fat thickness were different ($P < 0.05$) in steers from differing sized dams. Steers from small cows had decreased LM area compared to their counterparts with no difference between steers from moderate- or medium-sized cows. On the other hand, back fat thickness was greater for steers from small cows compared with steers from moderate- and medium-sized cows.

Conclusion

Cow size can have a big impact on cow-calf productivity in the Sandhills. As size increased, productivity of the cows and offspring increased linearly. However, it is important to note cows in this study were very moderate with few cows over 1,250 lb. Larger cows than cows in this study may have different results than reported here

Table 2. Effect of cow size on steer progeny feedlot performance

	Cow Size[1]				
Measurement	Small	Medium	Moderate	SEM	P-value
Feedlot performance, lb					
Entry BW	656^{a}	667^{b}	693^{c}	15	0.02
Reimplant[2] BW	1,027	1,042	1,068	22	0.07
Final BW	$1{,}399^{a}$	$1{,}413^{a}$	$1{,}469^{b}$	22	< 0.01
ADG, lb/d					
Entry to reimplant	4.07	4.04	3.91	0.30	0.71
Reimplant to final	3.75	3.81	3.83	0.18	0.74
Overall	3.91	3.95	3.88	0.13	0.66
Dry matter intake, lb					
Entry to reimplant	27.52	27.33	27.87	0.98	0.79
Reimplant to final	27.51	27.50	27.97	0.94	0.88
Overall	27.45	27.42	27.83	0.88	0.89
Gain:Feed					
Entry to reimplant	0.1485	0.1486	0.1366	0.0107	0.52
Reimplant to final	0.1377	0.1398	0.1354	0.0050	0.54
Overall	0.1463	0.1476	0.1421	0.0067	0.66
Carcass characteristics					
HCW, lb	881^{a}	890^{a}	925^{b}	14	< 0.01
Marbling[3]	506	506	505	16	0.99
LM area, in^2	14.07^{a}	14.22^{b}	14.41^{b}	0.12	0.05
Back fat, in	0.60^{a}	0.55^{b}	0.53^{b}	0.03	0.01
USDA yield grade	3.06	2.95	2.98	0.14	0.39

[abc]Within a row, means with differing superscript letter differ ($P < 0.05$).

[1]Cow size determined by adjusting cow BW at weaning to a BCS 5.

[2]Approximately, 100 d prior to slaughter.

[3]Marbling: $Small^{00}$ = 400, $Small^{50}$ = 450, $Modest^{00}$ = 500.

depending on the environmental conditions and constraints. In addition, this study does not take into account forage intake by cow size. As cow size increases, forage intake will increase. Due to the decrease in forage intake, cow herd size could be increased and offset the decreased reproductive performance in the small-sized cows.

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Evaluation of Lactation Demands on Nutrient Balance in Two Calving Seasons in Range Cows Grazing Sandhills Upland Range

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Summary with Implications

A modeling study evaluated the effects of milk production level on nutrient balance in March- and May-calving cows grazing Sandhills upland range during the breeding season. Forage quality of upland range peaks in June and steadily declines in July until November. In March-calving cows, metabolizable protein (MP) and energy were deficient by July 1 in all milking potential cows, which is exacerbated in greater milking potential cows. May-calving cows with 20 to 30 lbs of milk are predicted to enter the breeding season with a deficiency in MP and energy. In an effort to match cow type to environment in the Sandhills, producers should be selecting against high milk potential. With timing of forage quality decline and the start of breeding season in July, selecting for moderation in milk production becomes even more important in May-calving herds. Supplementation to meet MP deficiency with high ruminally undegradable protein supplements may be need in later breeding cows and younger cows in both March- and May-herds.

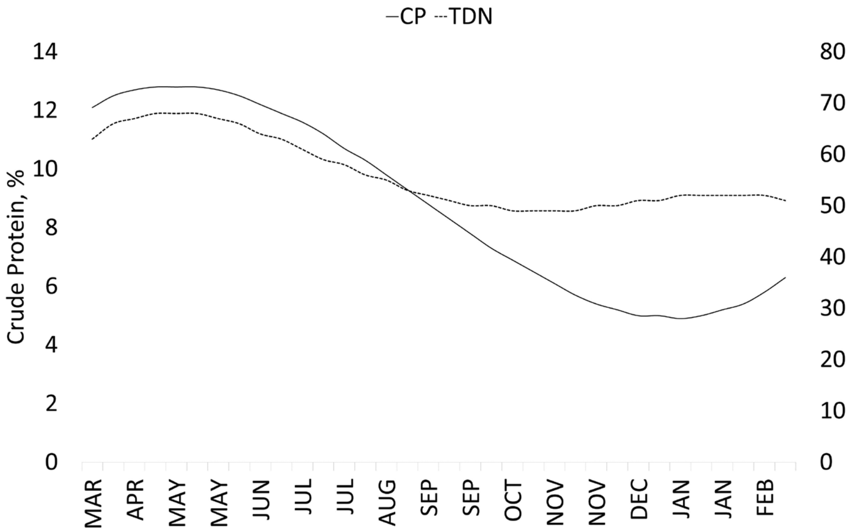

Figure 1. Laboratory analysis of range diet samples collected at Gudmundsen Sandhills Laboratory (Adapted from 1997 Nebraska Beef Report, pp 3–5).

Introduction

Selection for growth- oriented traits has been a focus in the beef industry in effort to maximize output. In doing so, cow-calf producers have tended to select for short-term traits such as growth and milk yield to increase weaning weights of calves for the potential to increase profitability. However, the economic value of reproduction is reported to be 5 times greater than growth or milk traits in beef cattle. Matching cow type or genetic potential to the production environment is and will be more important as cost of production increases. The continual increase in selection for milk production has resulted in range beef cows that are under greater nutritional stress in critical physiological periods, such as early lactation, that may ultimately reduce reproduction. Even in high feed quality environments, reproduction can be decreased in mature beef cows when peak milk production is greater than 20 lb per day. In addition, when selection of production traits exceed the capacity of the production environment, production efficiency decreases. With that in mind, increasing efficiency of livestock grazing range or pasture settings has to be focused on managing and selecting animals that fit their given environment and management. Therefore, the objectives of this study were to demonstrate nutrient balance of lactation in both March- and May-calving cows grazing Sandhills upland range with 20 to 30 lb of milk potential at peak lactation.

Procedure

Native range diets for this model were collected using esophageally-fistulated cows at the University of Nebraska's Gudmundsen Sandhills Laboratory (*1997 Nebraska Beef Cattle Report*, pp. 3–5). Samples were freeze-dried, ground, and analyzed for CP, in vitro dry matter digestibility, NDF, and ADF. Using the NRC model (NRC, 2010), net energy for maintenance, rumen degradable protein (RDP), and metabolizable protein balances were predicted for a March- and May-calving cow grazing Sandhills upland range during the breeding season. The nutrient values in the diet samples used in these analyses and the intake values used differ from those in another report (*2019 Nebraska Beef Cattle Report*, pp. 50–52). The primary differences are in diet TDN contents and estimated intake. These 2 factors tend to compensate across the 2 reports and estimate similar intakes of energy and protein.

Assumptions for the model were:

1. Cow body weight = 1200 lb
2. Body condition score = 5.0
3. Cow age = 48 months
4. Peak milk production = 20, 22, 24, 26, 28, or 30 lb
5. Estimates of dry matter intake were based on NRC model estimations
6. No additional supplementation was included in any calculation

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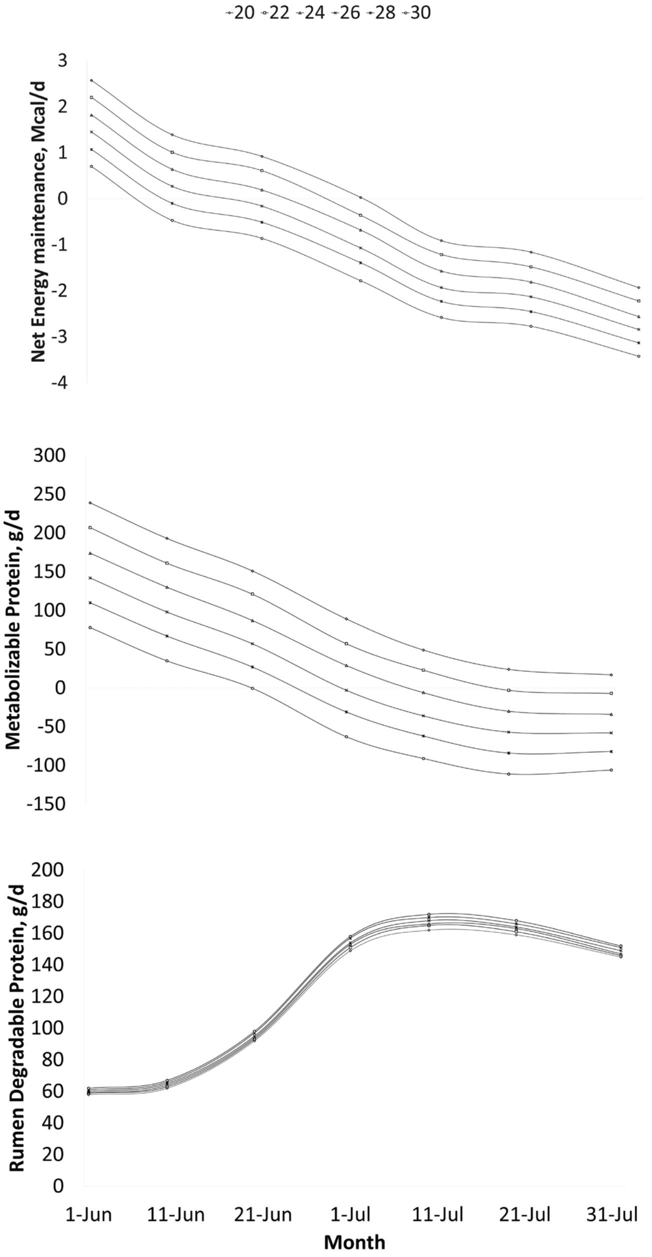

Figure 2. Evaluation of NEm (top graph), metabolizable protein (middle graph), and rumen degradable protein (bottom graph) balances for March-calving cow with milk production ranging from 20 to 30 lb of milk at peak lactation while grazing Sandhills upland range with a June 1st start of breeding date.

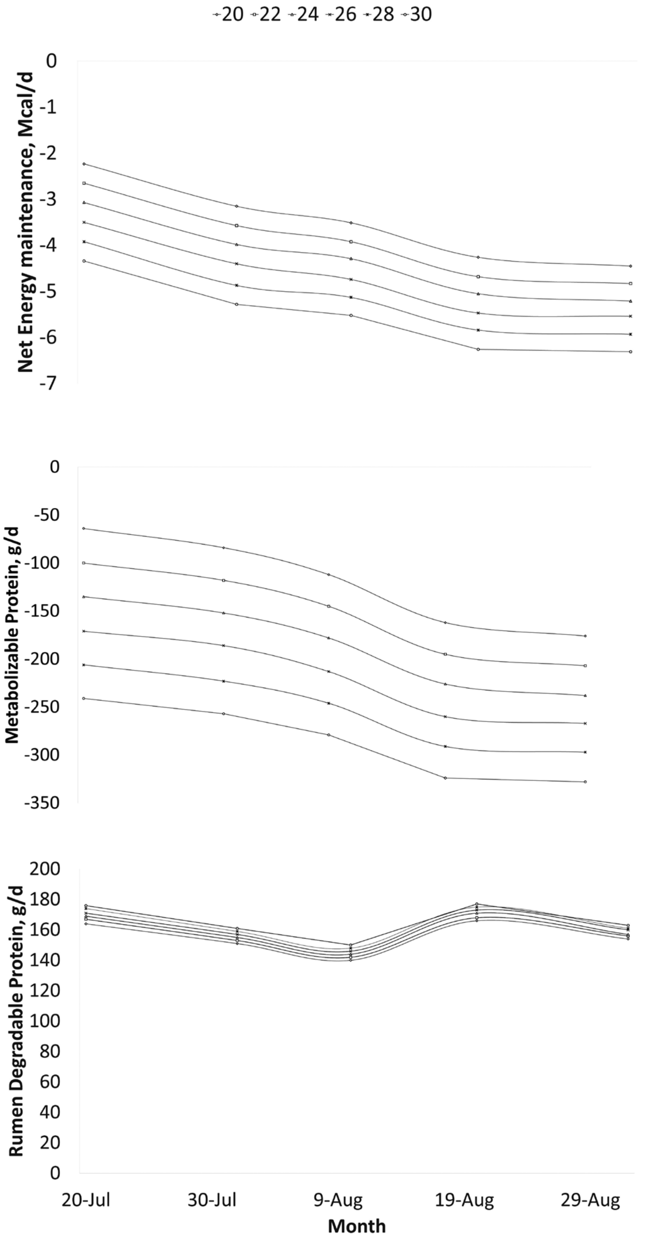

Figure 3. Evaluation of NEm (top graph), metabolizable protein (middle graph), and rumen degradable protein (bottom graph) balances for May-calving cow with milk production ranging from 20 to 30 lb of milk at peak lactation while grazing Sandhills upland range with a July 20th start of breeding date.

7. Breeding season started on June 1 for March-calving herd and July 20th for May-calving herd.

Results

Profit-motivated cow/calf operations must become more cost efficient to offset this increase in production costs. This increases the need for producers to match cow size and milk production potential to forage resources in order to optimize forage utilization and reproductive efficiency. Matching nutrient availability of range with nutrient requirements of the cow has been recommended to efficiently utilize forage quality. In doing so, changing calving date has been utilized to match nutrient requirement of genetic potential for milk production with the greatest nutrient value of the forage. Figure 1 illustrates the seasonal changes in crude protein and digestibility for esophageal diet samples collected from upland native range pastures at Gudmundsen Sandhills Laboratory. Peak CP and digestibility occurs in June, which occurs with the onset of the breeding season for a March-calving herd. As the season progresses, CP and digestibility decline until November.

March-calving Results

At the start of breeding in the March-calving herd, cows across all milking potential levels are predicted to be in a positive energy, MP and RDP balances. For all milk production levels, RDP was predicted to be in excess of requirements with RDP balance plateauing in the second week of July. As the breeding season progressing in June and July, both with energy (NEm) and MP balances are linearly decreasing across milking levels. Cows milking in excess of 28 lb of milk at peak lactation are in a negative energy balance by June 11th. By July 1st, all cows are predicted to be in a negative energy balance. With negative energy balance projected to occur within the first 30 days of the breeding season, reproductive performance may decline in cows that did not conceive early in the breeding season. Similar to NEm by July 1st, cows milking 26 lb or more at peak lactation would be in a deficit MP balance. By the end of breeding, only cows milking 20 lb of milk at peak were in a positive MP balance.

May-calving Results

Similar to March-calving herds, RDP balance was in excess and was predicted to be from 140 to 180 g/d above requirements during the entire breeding season. However, both NEm and MP balances were in a deficit at the start of breeding. Coming into the breeding season in a negative energy balance creates a scenario that cows have to have the ability to mobilize and utilize stored body fat effectively to reproduce. The energy and MP deficient puts more stress on younger, lactating cows. Young cows that are still growing and lactating with their first or second calf may drop out of the herd sooner in a May season due to decreased energy intake and reduced pregnancy rates. For instance, previous research has illustrated that pregnancy rates in mature cows from March or May-calving herd are similar (*2001 Nebraska Beef Cattle Report*, pp 8–9); however, pregnancy rates in May-calving heifers are decreased compared to March-calving heifers (*2017 Nebraska Beef Cattle Report*, pp 8–10). This may be partially due to an imbalance of milk production and environmental condition.

Conclusion

In general using the UNL diet model, the NRC predicted that a lactating March- and May-calving cow would not be deficient in RDP during the entire breeding season. In March-calving herds, the deficiency in MP and NEm occurred after 30 days of breeding when milk production was above 24 lb per day, which may create a situation that if cows don't get bred early then reproductive performance may decline as the breeding season progresses. In May-calving herds, lactating cows were deficient in MP and NEm during the breeding season. Summer calving cows With RDP requirements in surplus during the breeding season and as milk potential increases, there is a greater demand to supply supplementation that would meet the energy and MP deficit. Supplementation with a high RUP supplement with added energy such as distillers grains may still be needed in young cows to meet the deficiency in MP. Supplements high in RDP will likely not correct the MP and energy deficiencies. In addition, complementary forage systems (i.e., regrowth sub-irrigated meadow) may be utilized to increase performance in young range cows.

Moving cows from a spring-calving herd to a summer-calving herd matches calving date with increased quality forage to reduce feed costs compared to spring calving herds (*2001 Nebraska Beef Cattle Report*, pp. 8–9). However, due to the sharp decline in nutrient requirement at peak lactation (approximately 60 days postpartum) and during the breeding season, milk potential of the cowherd may have to decline as well to match the environment as shown with the greater nutritional deficit during breeding from 20 to 30 lbs of milk. In addition, drought conditions could exacerbate the deficiency in MP and energy in greater milk producing cows if forage conditions decline. Although, moving calving to a May-calving season may decrease winter feed cost, due to the forage quality during breeding, supplemental inputs during the breeding season may be greater in May-calving herds, especially in young range cows, to optimize pregnancy rates.

With current trends of selecting for increased output- oriented traits in purebred and commercial herds in the US, average milk production at peak lactation has increased in the mid to high 20 lb. The continual increase in selection for milk production in beef cows increases the nutritional stress in critical physiological periods, such as early lactation, and will ultimately reduce reproductive traits and/or increase production costs to maintain performance. This modeled dataset illustrates the need for future research focused on cow type (i.e. genetic potential for milk production) within timing of calving to optimize cow herd production in the Nebraska Sandhills.

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Impacts of 40 Years of the Gudmundsen Sandhills Laboratory on Beef Cattle and Range Systems

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The University of Nebraska (UNL) Gudmundsen Sandhills Laboratory (GSL) is a 12,800-acre research ranch in the Nebraska Sandhills. In 1978, Elmer "Pete" and Abbie Gudmundsen gifted the former Rafter C Ranch to the University of Nebraska Foundation. Thus, 2018 was the 40th year of UNL oversight of GSL. To the credit of UNL Administration, GSL development for range livestock research was delegated to a team of Research and Extension Specialists chaired by Dr. Don Clanton. Other members of that original team were Jim Nichols, Range Science; Gene Deutscher, Reproductive Physiologist; Dick Clark, Agricultural Economist; and Ivan Rush, Beef Extension Specialist. This team configured the ranch to investigate production and management questions pertinent to the region.

Our objective of this paper is to briefly describe impact on beef and range management systems resulting from visionary development of a working research ranch in the Nebraska Sandhills by the University of Nebraska.

One of the most significant accomplishments at GSL has been the development and implementation over the years of a systems approach to research. An example is that early work was primarily conducted on components of production. As time progressed, it became clear that a systems approach from pre-breeding to harvest better identifies and describes the overall impact on a ranch. A systems approach often changes the interpretation of results obtained from research dealing solely with segments of production systems.

Examples of the importance of considering the system, rather than individual components separately are the fetal programming work, calving date and weaning date systems, heifer development and grazing vs feeding harvested hay systems. The Nebraska Ranch Practicum is the education component to the systems work at GSL.

Some of the conclusions at the time of the research have changed as economics and deeper understanding of biological principles have evolved with time and further systems-based investigations. For example, market value of Sandhills pasture has increased at a greater rate than cost of feeding hay in the Sandhills. Therefore, this has changed the relationship between grazing and hay feeding in some situations.

Major evolution of impacts on beef and range systems from GSL are:

1. Development and implementation of a systems approach to research while training students in systems thinking.
2. Protein, rather than high levels of starch, is most always the preferred winter supplement for Sandhills forages.
3. Production systems using self-harvesting by grazing are typically most economical in Sandhills cow-calf systems.
4. June versus March calving for the Nebraska Sandhills beef systems best matches rangeland quality and quantity.
5. Validation of the NRC models for Nutrient Requirements of Beef Cattle in Sandhills systems.
6. Use of distiller's grains as supplements are used effectively to extend range capacity and provide a beneficial nutrient profile for gestating cows and yearlings when grazing cool-season meadow and upland range.
7. Time and type of supplementation affect prenatal fetal programming to impact changes in BCS, weight, carcass traits and cow productivity through epigenetic mechanisms.
8. Nebraska Ranch Practicum at GSL provides valuable, science-based, systems approach education to clientele in multiple states.
9. Heifer development systems are a key component of sustainable beef systems in the Nebraska Sandhills.
10. Proper sub-irrigated meadow management offers a key component to profitable forage management systems.

Summary and Implications

Gudmundsen Sandhills Laboratory has been, and will continue to be, a prized resource for training students, informing producers and exploring beef and range production systems. An example of this are the 105 articles that report research at GSL in Nebraska Beef Reports through 2018. We conclude that GSL provides an important resource for solving ranching problems in beef systems.

Confined Cow-Calf Production System and Post-Weaning Management Impact on Calf Production

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Summary with Implications

Calf performance was measured in a 3-yr study with a 2 × 2 factorial treatment design: 1) cow-calf production system (dry lot feeding or grazing corn residue) and 2) directly finishing calves or growing prior to finishing. Calves wintered on cornstalks were lighter at weaning than calves wintered in the dry-lot. However, following the finishing period, there were no effects of pre-weaning production system on final body weight or hot carcass weight. Calves directly adapted to a finishing diet had greater gain and improved efficiency compared to calves fed a grower diet prior to finishing. However, calves that were grown first produced 51 lb greater hot carcass weight. Directly finishing calves resulted in greater net profit as the extra hot carcass weight did not offset the cost of the additional 49 days in the feedlot. Wintering cows with calves on cornstalks instead of in a dry-lot resulted in lighter calves, but calves compensated in the feedlot.

Table 1. Composition of growing and finishing diets[1]

	Growing Diet		
Ingredient, % of diet DM	Year 1	Year 2	Year 3
Sweet Bran[1]	30	30	30
Wheat Straw	31	31	31
Modified distillers grains	35	-	-
Wet distillers grains	-	35	35
Supplement[2,3]	4	4	4
	Finishing Diet		
Ingredient, % of diet DM	Year 1	Year 2	Year 3
High moisture corn	50	51	51
Sweet Bran[1]	30	30	30
Wheat Straw	5	-	-
Grass Hay	-	5	5
Modified distillers grains	10	10	-
Wet distillers grains	-	-	10
Supplement[2,4]	5	4	4

[1] Sweet Bran sourced from Cargill Corn Milling, Blair, NE

[2] Supplement included limestone, trace minerals, and vitamin A,D,E premix

[3] Formulated for 200 mg/animal of Rumensin daily (Elanco Animal Health, Greenfield, IN)

[4] Formulated for 330 mg/animal of Rumensin and 90 mg/animal of Tylan daily (Elanco Animal Health)

Introduction

When traditional forage resources are limited, alternative beef production systems may be necessary. Research has demonstrated that year-round confinement of the cowherd can be used as an alternative to traditional pasture cow-calf production (*2015 Nebraska Beef Cattle Report,* pp. 15–18). In addition to alternative cow-calf production systems, different post-weaning management strategies may be implemented. Two common post-weaning systems are to either directly adapt calves to a finishing diet following weaning or grow the calves for a period of time prior to the finishing phase. Calves are commonly grown in an extensive system using grazed forages or crop residue. An alternative growing program consists of backgrounding calves in pens in which harvested forages are fed. The type of post-weaning management utilized can affect finishing performance and carcass characteristics. Research has indicated that calf-feds have improved feed efficiency, but yearlings gain faster and produce greater carcass weight (*2009 Nebraska Beef Cattle Report*, pp. 43–46). The objective of the current study was to evaluate cow-calf production system and post-weaning management on finishing performance and carcass characteristics of steer and heifer calves produced from an intensively managed cowherd.

Procedure

Summer-born steer (n = 114) and heifer (n = 95) calves [body weight (BW) = 582, standard deviation = 93 lb] were utilized in a study conducted over 3 years at the Eastern Nebraska Research and Extension Center (ENREC) feedlot. Calves were sourced from 2 cowherds maintained at either ENREC (124 calves) or the Panhandle Research and Extension Center (PREC; 85 calves). The study was completely randomized with a 2 × 2 factorial treatment design. Factors were 1) cow-calf production system and 2) post-weaning management.

Cow-calf Production System

Within each location, cowherds were maintained in confinement from approximately April to November during which the calving season occurred. In November, cow-calf pairs were assigned randomly to one of two winter cow-calf production treatments: 1) dry-lot feeding (DLOT) or 2) corn residue grazing with supplementation (STALK). Cow-calf pairs assigned to the DLOT treatment were limit-fed a distillers and crop residue-based diet formulated to meet energy requirements of a lactating cow in early gestation. The amount of dry matter (DM) offered increased monthly to account for increasing intake of the growing calf. Cow-calf pairs assigned to the STALK treatment were hauled to irrigated cornstalk fields and supplemented with approximately 5.3 lb (range of 3.7 to 7.1 lb) of a distillers-based cube daily. Calves from both cow-calf production systems were weaned in April and received into the EN-REC feedlot for post-weaning treatments.

Post-weaning Management

For post-weaning treatments, calves in the FINISH treatment were directly adapted to a concentrate finishing diet (Table 1) following weaning. In the GROW treatment, calves were fed a growing diet (Table 1) for approximately 76 days before being adapted to the same finishing diet as calves in the FINISH treatment.

Calves in the FINISH treatment began the finishing phase in April and were finished in November (196 DOF). Calves in the GROW treatment were fed a grower diet from April to July (76 DOF) and then adapted to a finishing diet for harvest in late December (169 DOF + 76). In year 1, calves were implanted with Revalor XS (steers; Merck Animal Health, Summit, NJ) or Revalor-IH (heifers; Merck Animal Health). Heifers were re-implanted with Revalor 200 (Merck Animal Health) approximately 100 days prior to harvest date. In years 2 and 3, all calves were implanted with Component TE-IS (steers; Elanco Animal Health) or Component TE-IH (heifers; Elanco Animal Health) at initial processing. All calves were then re-implanted with component TE-200 approximately 100 days before harvest. Ractopamine hydrochloride (Optaflexx; Elanco Animal Health) was included (300 mg/head daily) in the common finishing diet for the last 28 days on feed for all cattle every year.

Cattle were limit-fed a common diet for a minimum of 5 d prior to collecting initial body weight (BW) on 2 consecutive days. For calves in the GROW treatment, ending BW for the growing phase was used as initial BW for the finishing phase. To obtain a common physiological endpoint between treatments, ultrasonography was used to detect 12th rib fat thickness on GROW cattle approximately 40 d prior to projected harvest date each year. The ultrasound scans were then used to predict harvest date by targeting backfat thickness equal to FINISH cattle. On the day of harvest, hot carcass weight (HCW) and liver abscess scores were recorded. Following a 48-hour chill, 12th rib fat thickness, marbling score, and ribeye area were recorded. Final BW, average daily gain (ADG), and feed: gain (F:G) were calculated on a carcass-adjusted basis using a common dressing percentage of 63%.

Table 2. Economic assumptions applied to post-weaning management systems

	Treatments	
Item	FINISH[1]	GROW[2]
Growing phase		
Yardage, \$/hd daily	-	0.45
Health, \$/hd	-	15.00
Diet cost, \$/ton	-	156.49
Interest, %	-	6.2
Finishing phase		
Yardage, \$/hd daily	0.45	0.45
Health, \$/hd	15.00	15.00
Diet cost, \$/ton	188.15	188.15
Interest, %	6.2	6.2
Cattle Prices		
Feeder calf price[3], \$/lb	1.53	1.53
Feeder calf price[4], \$/lb	1.36	1.36
Selling price dressed basis[5], \$/lb	1.83	1.83
Interest, %	6.2	6.2

[1]FINISH = calves directly adapted to finishing diet following weaning

[2]GROW = calves fed grower ration for 76 d diet prior to finishing phase

[3]10-yr average calf price for steers and heifers weighing 500–600 lb.

[4]10-yr average calf price for steers and heifers weighing 600–700 lb.

[5]10-yr average live cattle price adjusted to a 63% dressing percentage for calculation of selling price on a dressed basis

Economic Analysis

A 10-year (2007–2016) analysis was used to economically compare post-weaning management systems. An average price of \$1.45/lb was used for the purchase of weaned steer and heifer calves (Table 2). A price slide of \$17.23 per cwt was used to account for differences in weaning weights between cow-calf production systems. The costs of distillers grains and Sweet Bran were calculated as 100% the value of \$4.59/bu corn. Base price for grass hay/wheat straw was \$50 per ton plus \$15/ton for processing. Supplement was priced at \$200 per ton. An interest rate of 6.2% was applied to the total cost associated with each phase and half of the initial animal cost. Feedlot yardage was held constant at \$0.45 per head per day for both treatments. Similarly, all cattle were charged \$15 per head for health and processing fees. A live cattle price (\$1.15/lb) was adjusted to a 63% dressing percentage to determine selling price (\$1.83/lb) on a dressed basis. Cost of gain (COG) in each phase was calculated by dividing costs associated with each phase (not including purchase price of the animal) by the BW gained during the phase.

Data were analyzed using the mixed procedure of SAS (SAS Institute, Inc., Cary, N.C.) as a completely randomized design. Experimental unit was pen with cow-calf production system, post-weaning management, and the cow-calf × post-weaning interaction included in the model as fixed effects. Location and year were included as random effects. Because the proportion of steers and heifers varied within pen,

Table 3. Effects of post-weaning management & cow-calf production system on finishing performance and carcass characteristics

	FINISH[1]		GROW[2]			*P*-value		
	DLOT[3]	STALK[4]	DLOT[3]	STALK[4]	SEM	Post-weaning	Cow-calf	Int.[5]
Growing performance								
Days on Feed			76	76				
Initial BW, lb	-	-	623	551	17	-	0.02	-
Ending BW, lb	-	-	832	785	17	-	0.11	-
DMI, lb/d	-	-	17.5	18.3	1.2	-	0.09	-
ADG, lb	-	-	2.68	3.01	0.21	-	0.03	-
F:G[6]	-	-	6.47	5.98	-	-	0.07	-
Finishing performance								
DOF	196	196	169	169				
Initial BW, lb	615	554	832	785	21	<0.01	<0.01	0.62
Final BW[7], lb	1310	1298	1392	1368	33	<0.01	0.15	0.65
DMI, lb/d	20.7	21.1	21.9	22.7	0.8	<0.01	0.08	0.60
ADG, lb	3.55	3.81	3.27	3.48	0.11	<0.01	<0.01	0.80
F:G[6]	5.80	5.55	6.66	6.57	-	<0.01	0.02	0.15
Carcass characteristics								
HCW, lb	825	817	879	862	21	<0.01	0.15	0.64
Ribeye area, in^2	13.6	13.8	13.9	13.7	0.3	0.66	0.92	0.15
12th rib fat, in	0.55	0.52	0.60	0.60	0.04	0.06	0.65	0.65
Marbling[8]	424[a]	422[a]	438[a]	491[b]	15	<0.01	0.05	0.04
Calc. Yield Grade	3.3	3.1	3.4	3.4	0.2	0.04	0.44	0.33

[1] FINISH = calves directly adapted to finishing diet following weaning

[2] GROW = calves fed grower ration for 76 d diet prior to finishing phase

[3] DLOT = winter dry-lot feeding of cow-calf pair prior to weaning

[4] STALK = winter corn residue grazing of cow-calf pair prior to weaning

[5] Test for cow-calf production by post-weaning management interaction

[6] Feed to Gain (F:G) was calculated and analyzed as Gain to Feed

[7] Calculated on a carcass-adjusted basis using a common dressing % (63%)

[8] Marbling score: 400 = Small, 500 = Modest, etc.

proportion of steers within each pen was included as a covariate for all variables.

Results

Performance of GROW cattle during the growing phase is presented in Table 3. Initial BW was lighter for calves that had previously been wintered on cornstalks compared to calves wintered in the dry-lot ($P = 0.02$). However, STALK calves had greater ADG ($P = 0.03$) and tended to have greater dry matter intake (DMI; $P = 0.09$) and improved F:G ($P = 0.07$) compared to DLOT calves.

No significant cow-calf production by post-weaning management interactions were observed for any finishing performance variables tested ($P \geq 0.15$; Table 3). Cattle that were previously wintered on cornstalks had lighter initial BW entering the finishing phase than cattle that had been wintered in the dry-lot ($P < 0.01$). However, STALK cattle appeared to have a compensatory response characterized by greater ($P \leq 0.02$) ADG and lower F:G and a tendency ($P = 0.08$) for greater DMI during finishing compared to DLOT cattle. When evaluating the effects of post-weaning management on finishing performance, GROW cattle had greater initial BW, final BW, and DMI compared to FINISH cattle ($P < 0.01$). However, cattle in the FINISH treatment had increased ADG and subsequently improved F:G compared to GROW cattle ($P < 0.01$).

The GROW cattle had 51 lb greater HCW compared to FINISH cattle ($P < 0.01$; Table 3). Twelfth rib fat thickness tended to be greater for GROW cattle relative to FINISH cattle ($P = 0.06$). The GROW cattle also had greater yield grade than FINISH cattle ($P = 0.04$). The GROW cattle could have been fed fewer days in order to be harvested at an equal fat endpoint as the FINISH cattle, which would have resulted in a smaller difference in HCW between treatments.

Economic Analysis

No significant cow-calf production by post-weaning management interactions were observed for any economic variables tested ($P \geq 0.57$; Table 4). Due to differences in initial BW, initial purchase cost during the growing phase was greater if calves had previously been wintered in the dry-lot compared to calves wintered on cornstalks ($P = 0.04$; Table 4). Although no significant difference between treatments was observed for growing cost ($P = 0.26$), growing COG

Table 4. Economic analysis of cattle by post-weaning management and cow-calf production system

	FINISH[1]		GROW[2]			*P*-value		
Item, $/animal	DLOT[3]	STALK[4]	DLOT[3]	STALK[4]	SEM	Post-weaning	Cow-calf	Int.
Growing Phase								
Purchase Cost	-	-	894.80	835.70	15.34	-	0.04	-
Growing Cost[5]	-	-	163.65	167.07	9.32	-	0.26	-
Growing COG[6]	-	-	78.37	70.73	7.68	-	0.10	-
Finishing Phase						-		-
Purchase Cost	891.72	834.44	-	-	14.8	-	0.01	-
Finishing Cost[5]	513.45	521.47	468.09	476.53	21.63	<0.01	0.21	0.98
Finishing COG[6]	71.81	68.27	81.82	79.46	1.71	<0.01	0.01	0.57
Total System Cost								
Total Cost	513.45	521.47	631.74	643.60	26.48	<0.01	0.25	0.81
Total COG[6]	71.81	68.28	80.09	76.39	2.27	<0.01	0.01	0.95
Total Revenue	1502.56	1488.62	1585.23	1578.92	36.89	<0.01	0.46	0.78
Net Profit	97.19	132.03	59.58	99.04	20.71	0.01	0.01	0.86

[1] FINISH = calves directly adapted to finishing diet following weaning

[2] GROW = calves fed grower ration for 76 d diet prior to finishing phase

[3] DLOT = winter dry-lot feeding of cow-calf pair prior to weaning

[4] STALK = winter corn residue grazing of cow-calf pair prior to weaning

[5] Total diet, yardage, health, and interest cost during the growing or finishing phase

[6] Cost of gain (COG; $/cwt) calculated by dividing costs associated with each phase (animal purchase costs and interest on the animal not included) by the BW gained during the respective phase

tended (*P* = 0.10) to be lower for STALK calves as a result of greater daily gain during the growing phase.

Likewise, initial purchase cost and COG during the finishing phase was greater for DLOT calves compared to STALK calves (*P* = 0.01; Table 4). When evaluating the main effects of post-weaning management on finishing variables, finishing cost was greater (*P* < 0.01) for FINISH cattle compared to GROW cattle largely due to FINISH cattle having 27 more DOF during the finishing phase. Conversely, finishing COG was less (*P* < 0.01) for FINISH cattle compared to GROW cattle due to FINISH cattle having improved F:G during finishing.

For the economics of total system (weaning through harvest), STALK cattle had less overall COG (*P* = 0.01; Table 4), which was a reflection of the improved F:G observed for STALK cattle relative to DLOT cattle. Although similar revenue (*P* = 0.46) was generated between treatments, STALK cattle produced $37 greater net profit than DLOT cattle (*P* = 0.01) as a result of reduced initial purchase cost of STALK cattle (due to less BW). Because of increased HCW, GROW cattle generated $86 greater total revenue in relation to revenue received from FINISH cattle. However, FINISH cattle had decreased total cost and COG, which subsequently resulted in $35 greater net profit compared to GROW cattle (*P* ≤ 0.01).

Previous research has shown growing cattle prior to finishing to be profitable. However, most of that work was done using grazed forages (grass, crop residues, or cover crops). Furthermore, these were calf-feds while much of the previous work has compared short and long yearlings. In the current analysis, the growing diet was 83% the cost of the finishing diet ($156/ton ÷ $188/ton). In order for net profitability to be equal between the GROW and FINISH treatments, the cost of the growing diet would need to be 58% ($108/ton) of the cost of the finishing diet.

Conclusion

Although calves wintered on cornstalks were lighter at weaning than drylot wintered calves, there were no significant differences in finished live weight or hot carcass weight due to pre-weaning management. Calves directly adapted to a finishing diet had greater gain and improved efficiency compared to calves fed a grower diet prior to the finishing phase. Although calves receiving the grower diet produced heavier carcasses, the extra days on feed made them less profitable than those calves directly placed on a finishing diet.

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Effects of Isolated Nutrients in Distillers Grains on Total Tract Digestibility and Digestible Energy in Forage Diets

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Summary with Implications

A digestion study was conducted to evaluate the contribution of individual nutrient components of distillers grains on nutrient digestibility and digestible energy. All diets contained 56% brome hay with a control diet containing either 40% corn; or 40% modified distillers grains. Four additional diets compared the contribution of fat, protein, fiber, and solubles components of distillers grains. No differences were observed for digestibility of DM, OM, and NDF among treatments. Feeding the isolated protein resulted in similar digestible energy to modified distillers grains, suggesting the bypass protein component contributes heavily to energy in distillers.

Table 1. Composition of diets (DM basis) fed to growing steers.

	Treatments					
Ingredient, % of DM	CON	DG	FIB	PROT	SOL	TAL
Brome	56.0	56.0	56.0	56.0	56.0	56.0
DRC[1]	40.0	-	20.0	20.0	25.0	37.0
Corn bran	-	-	20.0	-	-	-
CGM[2]	-	-	-	20.0	-	-
Tallow	-	-	-	-	-	3.0
MDGS[3]	-	40.0	-	-	-	-
Distillers Solubles	-	-	-	-	15.0	-
Supplement[4]	4.0	4.0	4.0	4.0	4.0	4.0
Nutrient Composition						
NDF$_{om}$[5], %	49.8	57.1	61.2	48.0	48.3	49.4
CP, %	12.4	19.3	12.9	22.6	14.1	12.1
Fat, %	3.34	5.47	3.39	2.33	3.02	6.15

[1] DRC: Dry rolled corn

[2] CGM: Corn gluten meal

[3] MDGS: Modified distillers grains plus solubles

[4] Supplements contained 1.4% limestone, 0.1% tallow, 0.3% salt, 0.05% trace minerals, 0.02% vitamin ADE, and 0.01% Rumensin. Supplements contained varying amounts of urea and fine ground corn so all diets met 12.5% CP at minimum. Diets were formulated to meet 200 mg/steer of Rumensin daily at 20 lb DM consumption.

[5] NDF$_{om}$: neutral detergent fiber accounted for ash.

Introduction

The ethanol industry is adopting new techniques that will remove oil and potentially fiber leading to changes in the byproducts available for cattle producers. Determining the contributions of nutrient components to the feeding value of distillers grains is important. It was previously observed that the feeding values for corn gluten meal, which provides rumen undegradable protein (RUP) identical to distillers, was similar to modified distillers grains (MDGS; *2016 Nebraska Beef Cattle Report*, pp. 29–30) when fed to growing cattle. Isolation and feeding of the fiber and solubles components of MDGS did not result in similar performance as MDGS fed at 40% of diet DM in forage growing diets, suggesting the greater protein content of MDGS contributes to the increase in feeding value. However, the effects of nutrient components on diet digestibility, fiber digestibility, and digestible energy were not evaluated.

The objectives of this study were to evaluate the contribution of different components of distillers grains on nutrient digestibility and digestible energy (DE) when replacing corn in high forage diets and to determine the effects of byproduct inclusion and type of fiber on in situ NDF disappearance.

Procedure

An 84-d digestibility study was conducted utilizing 6 ruminally cannulated steers (initial BW = 796 lb, SD = 59 lb). The study consisted of 6 periods, 14 d in length, allowing 10 d of adaptation to diets before 4 d of fecal collections. Steers were fed once daily at 0800 h and dosed intraruminally with titanium dioxide (5 g / dose) daily at 0800 and 1600 h (10 g / d). Steers were fed ad libitum on d 1–8 and fed 95% ad libitum on d 9–14. Feed refusals were collected daily and recorded prior to feeding and saved for d 9–12. Fecal grab samples were taken from steers on d 11–14 at 0700, 1100, 1500, and 1900 h.

Diets contained 56.0% brome and 40% concentrate (DM basis; Table 1). The control diet (CON) contained 40% dry-rolled corn (DRC) while the distillers grains diet (DG) contained 40% MDGS (DM basis). The remaining four diets replaced a portion of DRC and included the following byproducts selected to isolate the various nutrient components found in MDGS: 1) corn bran included at 20% of the diet DM to represent the fiber found in MDGS (FIB), 2) corn gluten meal included at 20% of the diet DM to represent the protein in MDGS (PROT), 3) tallow included at 3% of diet DM to represent the fat in MDGS (TAL), and 4) solubles (SOL) included at 15% of diet DM to represent the solubles found in MDGS. Inclusion of byproducts were chosen to simulate nutrient content provided by feeding 40% MDGS (DM basis).

Table 2. Total tract digestibilities and digestible energy of diets fed to growing steers.

	CON	DG[1]	FIB[2]	PROT[3]	SOL[4]	TAL[5]	SEM	*P*-values
DM								
Intake, lb / d	22.0	23.2	22.1	21.4	21.9	21.1	1.06	0.75
Output, lb / d	9.42	9.58	9.30	8.41	8.94	9.29	0.46	0.41
Digestibility, %	56.8	58.2	57.8	60.2	59.2	55.6	1.84	0.49
OM								
Intake, lb / d	20.6	21.2	20.7	20.0	20.0	19.7	0.97	0.87
Output, lb / d	8.11	8.11	8.00	7.11	7.64	7.95	0.42	0.38
Digestibility, %	60.2	61.2	61.2	63.8	62.1	59.2	1.83	0.49
NDF_{om}[6]								
Intake, lb / d	10.6^{b}	13.2^{a}	136^{a}	10.3^{b}	10.4^{b}	10.2^{b}	0.55	<0.01
Output, lb / d	4.96^{bc}	6.10^{a}	5.53^{ab}	4.65^{c}	4.93^{bc}	4.93^{bc}	0.26	<0.01
Digestibility, %	52.6	53.4	59.2	54.3	52.7	51.4	2.21	0.16
Fat								
Intake, lb / d	0.79^{b}	1.30^{a}	0.77^{b}	0.53^{c}	0.68^{b}	1.34^{a}	0.04	<0.01
Output, lb / d	0.15	0.22	0.15	0.18	0.15	0.15	0.02	0.16
Digestibility, %	80.3a^{b}	83.1^{a}	80.8a^{b}	67.5^{c}	75.6^{b}	89.0^{a}	2.77	<0.01
DE[7], Mcal / lb DM	1.12^{c}	1.38^{a}	1.20^{bc}	1.34^{a}	1.28^{ab}	1.20^{bc}	0.05	<0.01
TDN, %	56.1^{c}	69.2^{a}	59.9^{bc}	67.2^{a}	64.2^{ab}	60.0^{bc}	2.29	<0.01

[a,b]Means within a row with differing superscripts are different.

[1] DG: Modified distillers grains plus solubles replacing DRC at 40% diet DM.

[2] FIB: Replacing DRC with 20% diet DM corn bran.

[3] PROT: Replacing DRC with 20% diet DM CGM.

[4] SOL: Replacing DRC with 15% diet DM solubles.

[5] TAL: Replacing DRC with 3% diet DM tallow.

[6] NDF_{om}: neutral detergent fiber corrected for ash.

[7] DE: digestible energy.

Feed samples, feed refusals, and fecal samples were all composited by period and analyzed for DM, OM, NDF, and gross energy. Fecal samples were analyzed for titanium dioxide to determine daily fecal output. Digestibilities were then calculated by the following equation: (nutrient intake–nutrient output) / nutrient intake.

An *in situ* procedure was performed to determine disappearance of fiber from brome and bran within different diets. Dacron bags (Ankom Technology, Fairport, NY) with a 50-µm pore size (5 x 10-cm), were filled with 1.25 g of dried brome ground through a 2-mm screen or bran (not ground) and heat sealed. Two bags per sample were placed in mesh bags in the ventral rumen of each steer on d 14 and two bags per sample were set aside for time point 0 h to calculate wash out. Bags were incubated for 24 h and removed before feeding. All bags were washed and refluxed in NDF solution using the ANKOM Fiber Analyzer (Ankom Technology) to determine NDF disappearance.

All data were analyzed using MIXED procedures of SAS. Steer within period was the experimental unit. The model included period and treatment as independent fixed effects. *In situ* disappearance of NDF from bran or brome was analyzed with steer as the experimental unit. The model included diet, period and type of fiber (bran or brome) as fixed effects.

Results

No differences were observed in DM or OM intake ($P > 0.05$; Table 2). Fiber intake was affected by type of byproduct included in the diet ($P < 0.01$) with the FIB diet having the greatest NDF intake at 13.7 lb / d which did not differ in NDF intake from the DG diet (13.3 lb / d). All other diets had lower NDF intake ($P < 0.05$) but did not differ among one other. Fat intake differed among treatments with the TAL diet having the greatest fat intake at 1.34 lb / d which did not differ from DG diet (1.30 lb / d intake). The CON, FIB, and SOL diets were intermediate with the PROT diet having the lowest fat intake of all treatments ($P \leq 0.01$). Similar intake of NDF between FIB and DG and similar intake of fat between TAL and DG suggested that treatments were successful in matching nutrient intake.

No differences were observed in DM digestibility (DMD), OM digestibility (OMD), and NDF digestibility (NDFD) among treatments ($P > 0.05$; Table 2). Replacement of DRC with tallow resulted in greater fat digestibility (89.0%) compared to CON, FIB, PROT, and SOL ($P < 0.05$). Diets containing MDGS had similar fat digestibility to TAL ($P = 0.12$). Inclusion of MDGS also resulted in similar fat digestibility to CON and FIB ($P < 0.05$) and a tendency to be greater than SOL ($P = 0.06$).

Inclusion of MDGS and CGM resulted in increased DE (1.38 and 1.35 Mcal / lb; respectively) and the DG diet tended to be greater than SOL ($P = 0.10$). The SOL diet did not differ in DE from the FIB and TAL diets which had 1.21 and 1.20 Mcal / lb of DE, respectively. The CON diet had

Table 3. ***In situ*** **disappearance of fiber from different sources (bran vs. brome) in growing steers fed varying diets.**

	CON	DG[1]	FIB[2]	PROT[3]	SOL[4]	TAL[5]	SEM	*P*-value
Bran NDF disappearance[6], %	44.0	51.0	48.0	42.5	47.7	43.8	3.09	0.17
Brome NDF disappearance[6], %	33.6	39.9	34.9	34.2	39.2	33.4	2.20	0.12

[a,b,c]Means within a row with differing superscripts are different.

[1] DG: Modified distillers grains plus solubles replacing DRC at 40% diet DM.

[2] FIB: Replacing DRC with 20% diet DM corn bran.

[3] PROT: Replacing DRC with 20% diet DM CGM.

[4] SOL: Replacing DRC with 15% diet DM solubles.

[5] TAL: Replacing DRC with 3% diet DM tallow.

[6] NDF: Neutral detergent fiber disappearance after 24 h ruminal incubation.

the lowest DE (1.14 Mcal / lb) but did not differ from the FIB and TAL diets (*P* =0.20). Overall the increased DE for DG and PROT resulted in greatest calculated TDN values of 69.2% and 67.2%, respectively, when MDGS or CGM were included in the diet.

No interaction between diet and type of fiber (bran vs. brome) was observed (*P* = 0.83) for *in situ* NDF disappearance. No differences were observed for *in situ* NDF disappearance of bran or brome among diets (*P* ≥ 0.12; Table 3) averaging 46.2% for bran and 35.9% for brome.

Conclusion

The inclusion of byproducts increases TDN compared to DRC potentially due to the added energy density of fat, undegradable protein, and digestible fiber of byproducts. Relative to corn, MDGS has an increased fat content and fat digestibility. Greatest improvements in TDN were observed when feeding CGM and MDGS, suggesting the RUP contribution of MDGS explains the increased feeding value is underappreciated.

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Effects of Backgrounding and Feedlot System Strategies on May-Born Steer Performance

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Summary with Implications

May-born steers were backgrounded to achieve either a high or low rate of gain. The high rate of gain was achieved by offering steers meadow hay ad libitum and 4 lb/d of a 33% CP (DM) supplement, while the low rate of gain consisted of steers grazing meadow and offered 1 lb/d of the same supplement. After backgrounding, one-half of the steers from each group entered the feedlot in May as short-yearlings, while the remainder grazed upland range until entering the feedlot as long-yearlings in mid-September. Hot carcass weight was greater for steers backgrounded to achieve a high rate of gain, but they also consumed more during the feedlot phase and had fewer carcasses grade USDA average Choice or greater compared with steers backgrounded to achieve a low rate of gain. Long-yearling steers had increased marbling scores and percentage of carcasses grading USDA average Choice or greater compared with short-yearling steers. Furthermore, long-yearlings had increased carcass weight and risk for overweight carcasses.

Introduction

Historically, May-born calves wean at a lighter BW than March-born calves (*2018 Nebraska Beef Cattle Report*, pp. 15–17 and 21–23). Therefore, producers calving in May could increase calf BW before feedlot entry with overwinter backgrounding. Traditional backgrounding focuses on increased BW gain; however, mild nutrient restriction during backgrounding, followed by realimentation in the feedlot may alter metabolic function and increase energy utilization. Steers restricted during backgrounding typically undergo compensatory growth in the feedlot and reach a common fat thickness with fewer days on feed compared with unrestricted steers. May-born heifers developed on a low rate of gain overwinter exhibit compensatory gain when moved to a high-quality forage (*2018 Nebraska Beef Cattle Report*, pp. 24–27). Furthermore, using a low-cost, high-quality forage during the summer months to increase May steer BW before feedlot entry may optimize calf growth and forage resources. The objective of this study was to evaluate 2 backgrounding systems and 2 feedlot systems on May-born steer growth and carcass characteristics.

Procedure

A 6-yr study was conducted at the Gudmundsen Sandhills Laboratory (GSL), Whitman, and West Central Research and Extension Center (WCREC), North Platte, to examine how differing backgrounding systems and feeding systems affect May-born steers.

Backgrounding System

At weaning in January, May-born steers at GSL were blocked by wean BW and assigned randomly to 1 of 2 backgrounding systems until approximately May 8. Steers assigned to a high-input system (HI; n = 194, 428 ± 9 lb) were offered meadow hay ad libitum and 4 lb/d of a 33% CP supplement (DM, Table 1). The remaining steers were assigned to a low-input system (LO; n = 198, 437 ± 9 lb) and grazed sub-irrigated meadow and were offered 1 lb/d of the same supplement.

Feedlot System

At the conclusion of the backgrounding period in May, one-half of the steers from each backgrounding system were transported to WCREC and placed in a feedlot for 212 d (S-YRL; n = 195, 551 ± 4 lb). Steers in the S-YRL system were implanted with Synovex Choice at feedlot entry. The remaining steers (L-YRL; n = 197, 765 ± 4 lb) were implanted with Revalor G and grazed upland range at GSL. The L-YRL steers were transported to the WCREC feedlot approximately Sept. 14, implanted with Ralgro at feedlot entry, and remained in the feedlot for 171 d.

Both S-YRL and L-YRL steers were adapted to a common feedlot diet over 21 d consisting of 48% dry rolled corn, 40% wet corn gluten feed, 7% prairie hay, and 5% supplement (DM basis). The supplement included vitamins, minerals, monensin (1.3 g/lb; Rumensin, Elanco Animal Health, Indianapolis, IN), and tylosin (1.0 g/lb; Tylan 40, Elanco Animal Health). Steers were reimplanted with Synovex Plus 110 d after feedlot entry for S-YRL steers and 70 d for L-YRL steers. Hot carcass weight (HCW) was recorded at slaughter and carcass data collected following a 24-h carcass chill.

Table 1. Nutrient analysis of supplement[1] provided to steers during backgrounding phase[1]

Item	
Nutrient	
CP, % (DM)	32.9
RUP, % CP	39.7
TDN, % (DM)	78.4
Ingredient, % DM	
Dried distillers grains meal	52.5
Soybean meal (46.5% CP)	14.7
Vitamin and mineral package[2]	13.3
Wheat middlings	6.3
Sunflower meal (35% CP)	6.3
Molasses, liquid	3.7
Urea	1.6
Cull Beans	1.5

[1] At January weaning, steers were blocked by BW and assigned to 1 of 2 development treatments until May 8: HI = each steer offered meadow hay ad libitum plus 4 lb/d supplement cube, LO = each steer grazed dormant subirrigated meadow plus 1 lb/d of the same supplement.

[2] Supplement formulated to provide 0.7 g/lb Monensin (Rumensin, Elanco Animal Health, Indianapolis, IN).

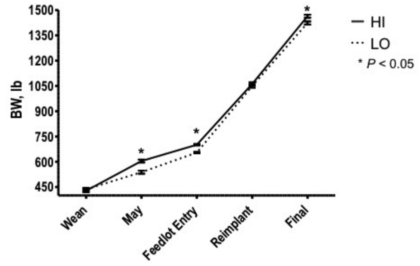

Figure 1. The effects of backgrounding treatment on May-born steer BW. At weaning in January, steers were blocked by BW and assigned to 1 of 2 development treatments until May 8: HI steers were offered meadow hay ad libitum plus 4 lb/d 33% CP (DM) cube, while LO steers grazed subirrigated meadow plus 1 lb/d of the same supplement.

Table 2. Effect of backgrounding treatment[1] on May-born steer ADG, DMI, F:G, and RFI values

	HI	LO	SEM	TRT
Background ADG, lb[2]	1.41	0.77	0.07	< 0.01
Feedlot ADG, lb	4.10	4.03	0.04	0.30
DMI, lb/d	27.8	27.1	0.2	0.03
DMI, % BW	2.6	2.6	0.02	0.45
F:G, lb:lb	7.0	6.8	0.2	0.06
RFI[3]	0.027	-0.047	0.073	0.47

[1] At January weaning, steers were blocked by BW and assigned to 1 of 2 development treatments until May 8: HI = each steer offered meadow hay ad libitum plus 4 lb/d 33% CP (DM) supplement cube, LO = each steer grazed dormant subirrigated meadow plus 1 lb/d of the same supplement.

[2] Background ADG = January 8 weaning to an average date of May 8.

[3] RFI = residual feed intake where RFI = Actual DMI–[group average DMI + [b_m × (individual mid-test $BW^{0.75}$–group average mid-test $BW^{0.75}$ + [b_g × (individual ADG–group average ADG)] where b_m is the slope coefficient for mid-test BW and b_g is the slope coefficient for ADG when regressed against DMI.

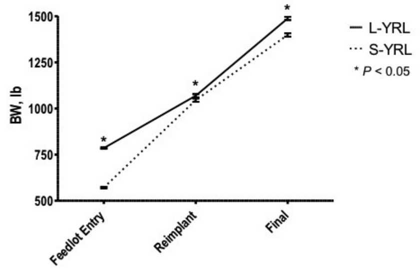

Figure 2. The effects of feedlot system on May-born steer BW. S-YRL steers entered the feedlot at an average day of May 8, immediately following backgrounding treatment and remained in the feedlot for 212 d. L-YRL steers grazed summer range following backgrounding treatment and entered the feedlot for 171 d at an average date of Sept. 14.

Final BW was calculated by adjusting HCW to a common dressing percentage of 63%. Percentage of empty body fat (EBF) was calculated using EBF = 17.76107+(1.84308 × FT)+(0.04288 × HCW)+(0.81855 × QG)-(0.02659 × LMA); where FT = 12th rib fat thickness (in), HCW = hot carcass weight (lb), QG = quality grade (4 = Select, 5 = Choice–, 6 = Choice^0, 7 = Choice $^+$, 8 = Prime), and LMA = *longisimuss* muscle area (in^2).

GrowSafe Feeding System

Feedlot intake data was unavailable for steers in the first year of the study. In yr 2 to 6, a GrowSafe feeding system (GrowSafe Systems Ltd., Airdrie, AB, Canada) was acquired and steers were placed in the system upon feedlot entry. No intake data were included from the initial 2 wk adaptation period or on the day of shipping. Recorded daily intakes from the GrowSafe system were used to calculate DMI, G:F, and residual feed intake (RFI). Residual feed intake was considered as the actual DMI minus predicted DMI. Predicted DMI was calculated using the following equation. Predicted DMI = Group avg. DMI + [b_m × (Indiv. midBW$^{0.75}$ – Group avg. midBW$^{0.75}$)] + [b_g × (Indiv. ADG – Group avg. ADG)] where midBW$^{0.75}$ = mid-test metabolic BW and was predicted using the equation: Feedlot entry BW + [ADG × (Total days in feedlot ÷ 2)]. Any daily DMI values above or below 4 standard deviations from the group mean for system within yr were considered outliers and excluded from the data.

Statistical Analysis

All data were analyzed using the PROC GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC, version 9.4). The experimental unit was considered as treatment × year, where treatment was either backgrounding system or feedlot system. The model statement included the fixed effects of background treatment, feedlot system, and the resulting interaction. No significant interactions were detected between backgrounding treatment and feedlot system, so main effects are reported. Year was included as a covariate in all analyses and was removed when $P > 0.05$. Data were considered significant at $P \leq 0.05$ and a tendency if $P \leq 0.10$ and $P > 0.05$.

Results

Backgrounding System (HI vs LO)

The effects of backgrounding treatment on steer BW are presented in Figure 1. Initial BW was similar ($P = 0.50$) between treatments. Steers assigned to the HI system had a greater ($P < 0.01$) May BW, feedlot entry BW, and final BW, but had a similar ($P = 0.24$) reimplant BW. Corresponding with their increased May BW, HI steers had a greater ($P < 0.01$) backgrounding average daily gain (ADG, Table 2).

Steer ADG and feedlot measurements are presented in Table 2. There were no differences ($P = 0.30$) in ADG over the entire feeding period. Steers assigned to the LO treatment tended ($P = 0.06$) to have decreased F:G ratios, which is a result of LO steers having decreased ($P = 0.03$) feedlot DMI, but similar ($P = 0.30$) ADG. Dry matter intake as a percentage of BW was similar ($P = 0.45$) between treatments. Furthermore, RFI values were also similar ($P = 0.47$) between treatments.

The effects of backgrounding system on steer carcass characteristics is presented in Table 3. Hot carcass weight (HCW) was heavier ($P < 0.01$) for HI steers due to increased final BW. Percent EBF, 12th rib fat, and LM area were similar ($P \geq 0.13$) between treatments. Likewise, yield grade was also similar ($P = 0.73$) between treatments. Steers assigned to the LO backgrounding system tended ($P = 0.10$) to have increased marbling scores, which resulted in a tendency ($P = 0.09$) for more LO steers to grade USDA average Choice or greater. Furthermore, LO steers had fewer ($P \leq 0.04$) carcasses weighing greater than 1,000 lb.

Feedlot System (S-YRL vs L-YRL)

Steers assigned to the L-YRL system had a greater ($P \leq 0.03$) BW at all time points (Figure 2). Steer feedlot performance is presented in Table 4. Steers in the L-YRL system had increased ($P \leq 0.05$) total ADG. Dry matter intake was greater ($P < 0.01$) for L-YRL steers, but L-YRL had a decreased ($P < 0.01$) DMI as a percentage of BW. Steers in the S-YRL system had decreased ($P < 0.01$) F:G ratios, but no differences were detected ($P = 0.68$) in RFI between treatments.

Carcass characteristics of steers in each feedlot system is presented in Table 5. Corresponding with an increased final BW, HCW was greater ($P < 0.01$) for L-YRL steers, which may have resulted in an increased ($P < 0.01$) percentage of L-YRL steers with 1,000 lb carcasses. Percent EBF was increased ($P < 0.01$) for L-YRL steers, although there were no differences ($P = 0.31$) in 12th rib fat thickness. Additionally, L-YRL steers had a greater ($P \leq 0.04$) LM area and yield grade. Marbling score was increased ($P < 0.01$) for L-YRL steers. This may have caused a tendency ($P = 0.10$) for a greater percentage of L-YRL steers to grade USDA low Choice or greater, and for a greater ($P < 0.01$) percentage of L-YRL steers grading USDA average Choice or greater.

Conclusions

Steers backgrounded on the LO system weighed less at the conclusion of the backgrounding and feedlot phases; however, these steers consumed less feed in the feedlot and had decreased F:G ratios. Furthermore, LO steers tended to have a greater percentage of carcasses grading USDA average Choice or greater, and fewer overweight carcasses compared with HI steers. Steers in a L-YRL feedlot system weighed more at slaughter and consumed less feed per lb of BW, although they had increased F:G

Table 3. Effect of backgrounding treatment[1] on May-born steer carcass characteristics

	HI	LO	SEM	*P*–value
HCW, lb	922	897	7	< 0.01
EBF, %[2]	35.1	35.1	0.2	0.96
Marbling score[3]	468	482	6	0.10
12th rib fat, in	0.59	0.59	0.02	0.83
LM area, in^2	14.8	14.6	0.1	0.13
Yield grade	3.3	3.2	0.1	0.73
Choice$^-$ or greater, %	82	87	3	0.19
Choice^0 or greater, %	21	29	4	0.09
Carcass size				
% ≥ 1,000 lb	17	10	3	0.03
% ≥ 1,050 lb	5	2	2	0.04

[1] At January weaning, steers were blocked by BW and assigned to 1 of 2 development treatments until May 8: HI = each steer offered meadow hay ad libitum plus 4 lb/d 33% CP (DM) supplement cube, LO = each steer grazed subirrigated meadow plus 1 lb/d of the same supplement.

[2] EBF = empty body fat where EBF = 17.76107 + (1.84308 × FT) + (0.04288 × HCW) + (0.81855 × QG)–(0.02659 × LMA), where FT = 12th rib fat thickness (in), HCW = hot carcass weight (lb), QG = quality grade (4 = Select, 5 = Choice–6 = Choice, 7 = Choice +, 8 = Prime), LMA = LM area (in^2).

[3] 300 = slight^{00}, 350 = slight^{50}, 400 = small^{00}, 450 = small^{50}, 500 = modest^{00}.

Table 4. Effect of feedlot system[1] on May-born steer ADG, DMI, F:G, and RFI values

	L-YRL	S-YRL	SEM	TRT
Feedlot ADG, lb	4.14	4.01	0.04	0.05
DMI, lb/d	28.9	26.0	0.2	< 0.01
DMI, % BW	2.5	2.7	0.02	< 0.01
F:G, lb:lb	7.1	6.6	0.2	< 0.01
RFI[4]	0.011	-0.031	0.074	0.68

[1] Feedlot system: S-YRL = steers entering feedlot at an average date of May 8 and fed for 212 d, L-YRL = steers entering feedlot at an average date of Sept. 14 and fed for 171 d.

[3] RFI = residual feed intake where RFI = Actual DMI–[group average DMI + [b_m × (individual mid-test $BW^{0.75}$–group average mid-test $BW^{0.75}$ + [b_g × (individual ADG–group average ADG)] where b_m is the slope coefficient for mid-test BW and b_g is the slope coefficient for ADG when regressed against DMI.

Table 5. Effect of feedlot system[1] on May-born steer carcass characteristics

	L-YRL	S-YRL	SEM	*P*–value
HCW, lb	937	882	7	< 0.01
EBF, %[2]	35.6	34.7	0.02	< 0.01
Marbling score[3]	491	459	6	< 0.01
12th rib fat, in	0.63	0.59	0.02	0.31
LM area, in^2	14.8	14.5	0.1	0.02
Yield grade	3.3	3.2	0.1	0.04
Choice$^-$ or greater, %	87	81	3	0.10
Choice^0 or greater, %	32	19	4	< 0.01
Carcass size				
% ≥ 1,000 lb	25	6	3	< 0.01
% ≥ 1,050 lb	8	1	2	< 0.01

[1] Feedlot system: S-YRL = steers entering feedlot at an average date of May 8 and remained in the feedlot for 212 d, L-YRL = steers entering feedlot at an average date of Sept. 14 and remained in the feedlot for 171 d.

[2] EBF = empty body fat where EBF = 17.76107 + (1.84308 × FT) + (0.04288 × HCW) + (0.81855 × QG)–(0.02659 × LMA), where FT = 12th rib fat thickness (in), HCW = hot carcass weight (lb), QG = quality grade (4 = Select, 5 = Choice$^-$, 6 = Choice, 7 = Choice$^+$, 8 = Prime), LMA = LM area (in^2).

[3] 300 = slight^{00}, 350 = slight^{50}, 400 = small^{00}, 450 = small^{50}, 500 = modest^{00}.

ratios. At slaughter, L-YRL steers produced heavier carcasses, which resulted in more overweight carcasses. Additionally, L-YRL steers had increased marbling scores and an increased percentage of steers grading USDA average Choice or greater. Use of a low-input backgrounding system may increase May-born steer profitability in the feedlot phase. Furthermore, grazing of May-born steers on a low-cost forage prior to feedlot entry may result in more valuable carcasses, although the risk for overweight carcasses is increased.

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Effects of Supplemental SoyPass in Forage-Based Diets Containing Distillers Grains on Performance of Growing Steers

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Summary with Implications

SoyPass was supplemented in two grass hay diets containing 20% or 35% wet distillers grains with solubles (WDGS) to analyze the effects on growing cattle performance. The SoyPass supplement replaced 0, 30, or 60% of dietary WDGS for a total of 6 treatments with a factorial design. Substituting SoyPass into the diet did not affect average daily gain (ADG) of calves; however, calves consuming the 35% WDGS diet gained 31% more than the 20% WDGS treatment calves. Dry matter intake (DMI) and feed to gain (F:G) increased linearly in the 35% WDGS diet with the inclusion of SoyPass. In the 20% WDGS diet, DMI and F:G were maximized when SoyPass replaced 30% of the WDGS and lowest when SoyPass replaced 60% of WDGS. Therefore, SoyPass can replace up to 60% of the WDGS in forage based diets containing 20% WDGS with no adverse effects on performance by appearing to supply needed lysine.

Introduction

Growing cattle require increased quality and quantity of metabolizable protein compared to older more mature animals in order to meet the animal's demand for amino acids used for muscle growth. Typically, diets formulated for growing cattle contain large amounts of forage and smaller amounts of grain and by-products. While forage CP can be high, the majority of that protein is rumen degradable protein, which is fermented to meet the requirements of the ruminal microbial population. In many cases, microbes cannot provide enough protein and more cannot be made as dietary energy limits production. Corn distillers grains (DGS) is often used as a bypass protein supplement as a large portion (63%) of its protein is not ruminally degraded and is available for utilization by the animal.

Methionine and lysine are two of the first-limiting amino acids in most growing cattle diets. Corn and its by-products contain large amounts of methionine but are lower in lysine. Conversely, soybean products contain low-levels of methionine but concentrated amounts of lysine. The purpose of this study was to replace DGS with SoyPass (a bypass soybean meal product) in a forage-based growing diet to evaluate response to bypass lysine for growing calves.

Table 1. Experimental diets

	Wet distillers grains with solubles (WDGS) supplement					
	20%			35%		
	SoyPass replacing WDGS, %					
Ingredient, %DM	0	30	60	0	30	60
Brome hay	77	77	77	62	62	62
Supplement[1]	3	3	3	3	3	3
WDGS	20	14	8	35	25	15
SoyPass	0	6	12	0	10	20
Nutrient						
CP, % DM	13	14	15	16	18	23
RUP, % of CP	31	36	41	43	48	53
Lysine, % DM	0.40	0.48	0.57	0.53	0.67	0.90

[1]Supplement formulated to provide 1.22% fine ground corn, 1.34% limestone, 0.08% tallow, 0.3% salt, 0.05% beef trace mineral, and 0.02% vitamins A-D-E on DM basis

Procedure

Two groups of 60 growing steers (initial BW 582 ± 30 lb and 664 ± 75 lb) were utilized to study the effects of replacing DGS with SoyPass (0%, 30%, or 60% of DGS) in grass hay diets containing 35% or 20% DGS (Table 1). The study was arranged as a 2 × 3 factorial design and the feeding period was 84 d. Two separate groups of animals were utilized to observe the effect of stage of growth on metabolizable protein requirements. Steers were individually fed to ensure ad libitum intakes utilizing the Calan gate system at the Eastern Nebraska Research and Extension Center (ENREC) located near Mead, NE.

Steers were limit-fed a common diet containing 50% Sweet Bran (Cargill Corn Milling, Blair, NE) and 50% alfalfa hay at 2% of BW for 5 d followed by 3 d of weighing. The average of the 3-d weight served as initial BW and this procedure was replicated at the end of the study to measure ending BW. Additionally, all steers were implanted on d 1 with Synovex S (Zoetis, Parsippany, NJ). On d 43 for both groups of cattle, a blood sample was collected and analyzed for serum urea nitrogen for the first group and plasma urea nitrogen for the second group.

Performance results and blood urea nitrogen data were analyzed using the MIXED procedure of SAS. Initially, block of cattle, level of DGS, level of SoyPass supplement, and the interaction served as fixed effects in the model. Because there were no treatment × block interactions ($P \geq 0.10$), the interaction was removed from the final

Table 2. Performance of growing cattle on forage-based diets supplemented with SoyPass

	Wet distillers grains with solubles supplement									
	20%			35%						
	SoyPass replacing WDGS, %						SEM	*P*-value		
Item	0	30	60	0	30	60		Dist	SoyP	Int
IBW[1], lb	623	624	621	625	622	622	13	0.97	0.99	0.98
EBW[2], lb	787	778	781	836	830	829	14	<0.01	0.84	0.99
DMI, lb	17.7^{bc}	18.4^{ab}	16.9^{c}	17.8^{bc}	18.6^{ab}	19.7^{a}	0.47	0.01	0.30	0.01
ADG, lb	1.96	1.83	1.91	2.52	2.48	2.47	0.07	<0.01	0.49	0.76
F:G	9.1^{ab}	10.2^{a}	8.9^{bc}	7.0^{e}	7.4^{de}	8.0^{cd}	-	<0.01	0.17	0.03

[1] Initial body weight

[2] Ending body weight

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

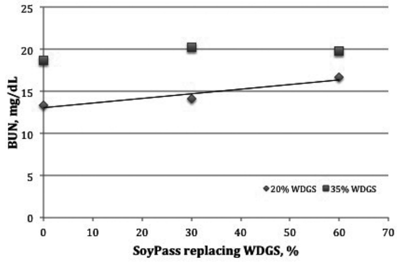

Figure 1. Blood urea nitrogen increased with increasing SoyPass in 20% distillers grains diets. SoyPass was supplemented to replace 0, 30, or 60% of distillers grains in grass hay diets formulated to contain 20 or 35% WDGS. Main effect of distillers grains inclusion ($P < 0.01$; SEM = 0.35), SoyPass inclusion ($P < 0.01$; SEM = 0.44), and the interaction ($P = 0.04$; SEM = 0.61).

analysis and data from both blocks of cattle were combined for analysis with block as a fixed effect. Additionally, where SoyPass × DGS interactions were detected, SoyPass inclusion was analyzed using covariate regression within DGS inclusion.

Results

There were no interactions detected for ADG between SoyPass supplementation and level of DGS in the diet ($P = 0.76$; Table 2). Additionally, SoyPass inclusion had no effect on ADG ($P = 0.49$). However, ADG was increased for steers consuming the 35% DGS diet compared to steers offered the 20% distillers ration (2.49 vs. 1.90 lb, respectively; $P < 0.01$).

A SoyPass × DGS interaction was detected ($P = 0.01$) for DMI. As SoyPass replaced DGS in the 35% diet, DMI increased linearly (linear $P = 0.01$). In the 20% DGS diet, DMI decreased as SoyPass replaced 60% of the DGS compared to 30% ($P = 0.02$). Therefore, there was also an interaction between SoyPass and DGS for F:G ($P = 0.03$) with a linear increase ($P = 0.01$) in F:G as SoyPass replaced DGS in the 35% treatment and a quadratic increase ($P = 0.02$) detected for the 20% WDGS treatment. On average, F:G was improved 20% for cattle consuming the 35% diet compared to 20% (7.5 vs. 9.4, $P < 0.01$).

Blood urea nitrogen increased linearly as SoyPass replaced distillers in the 20% diet ($P = 0.01$), which reflects the increased dietary CP and RUP content (Figure 1). Blood urea nitrogen was not affected by SoyPass substitution in the 35% diet, likely due to the animal's capacity to excrete urea being maximized under all 3 dietary conditions.

Performance results may be explained by both metabolizable protein and energy balance. In the 35% DGS diet, metabolizable protein was provided above requirements and may have supplied sufficient lysine. Likely because of the oil in DGS, DGS supplied more energy than the SoyPass. In the 20% DGS diet, F:G was not affected by SoyPass level, even though there is less energy in the SoyPass than in the distillers grains. This suggests metabolizable lysine may have been limiting with only DGS and the SoyPass supplied needed lysine.

Conclusion

Overall, forage-based growing diets formulated with low-levels of distillers grains (< 20%) may be deficient in metabolizable lysine, which could be corrected by the inclusion of SoyPass. Furthermore, cattle demonstrated increased performance when fed the 35% distillers diet compared to the 20% because both dietary energy and metabolizable protein balance were improved.

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Economics of Field Pea Supplementation for Cattle Grazing Crested Wheatgrass

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Summary with Implications

Heifers grazing crested wheat grass were supplemented either field peas or dried distillers grains plus solubles (DDGS) at 0.4% or 0.8% of body weight. Heifers supplemented with field peas had 10% lower daily gain compared to their DDGS supplemented counterparts. The decision to supplement field peas for producers depends on the price at which field peas can be acquired, as well as the distance that DDGS has to be hauled in order to be utilized. Field peas are a viable option in western Nebraska as a supplement for grazing cattle when DDGS is unavailable or field peas are in excess and can be obtained below the human consumption and pet food market price.

Introduction

Field peas, grown in rotation with wheat in western Nebraska, offer nitrogen fixation, weed control, pest control, and other benefits to crops that follow them in a rotational growing system. However, the human consumption market and the pet food industry, both of which are markets for field peas produced in the western part of Nebraska, quickly become saturated due to the slow processing procedure. Producers growing these peas are forced to either store their commodity, sell them at a discounted price, or find a way to utilize them in their own operation when markets are saturated. Field peas are a high crude protein (CP) feed (23–26% CP) that is approximately 40% rumen undegradable protein (RUP). Distillers grains plus solubles (DDGS) is a popular protein supplement in regions of Nebraska where ethanol plants are abundant. However, DDGS often have to be shipped several hundred miles to be used as a protein supplement in western Nebraska, whereas field peas are locally available. The value of field peas in cattle diets has been evaluated in finishing diets when replacing corn, but little work has been done evaluating field peas as a protein supplement for growing cattle on grass. Also, the value of field peas as a supplement is largely unknown and needs to be evaluated. Therefore, the objectives of this study were to determine the value of field peas as a supplement to grazing cattle, and to determine a pricing mechanism relative to DDGS.

Procedure

A two year grazing trial was conducted at the High Plains Ag Lab (HPAL) near Sidney, NE that utilized a total of 226 yearling heifers. The first year was conducted during the summer of 2016 and utilized 112 heifers [body weight (BW) = 647, standard deviation (SD) = 76 lbs] grazing from May 20 through September 19. Year 2 was conducted during the summer of 2017 and utilized 114 heifers (BW = 674, SD = 36 lbs) that grazed from May 23 through September 7. The trial was set up in a 2×2 factorial design with supplement level and supplement type being the two factors. Cattle were blocked into a light, medium, and heavy body weight. Treatments included field peas or DDGS supplemented daily at either 0.4% or 0.8% of BW. Weekly supplement amounts were prorated for 6 days of delivery and fed in bunks. Cattle were rotated every two weeks in order to remove any effect of pasture on performance. Initial BW was calculated by averaging a 2 day initial weight, and supplement level was determined based on this weight. Interim weight was collected during the middle of the trial in order to adjust the supplement amount for the remainder of the trial. Ending BW was calculated by averaging 2 day weights off of grass as well. Each treatment was replicated 6 times (3/yr) over the 2 year study. Pasture was the experimental unit and block and year were treated as fixed effects. Effects of weight block and year were not significant ($P \geq 0.26$) and were removed from the model. Average daily gain (ADG) was calculated based on initial and ending BW and economics were determined based on ADG. The economic analysis was calculated by using the percent change in the performance (ADG) of the different treatments of heifers.

Results

There was no interaction between type and level of supplement (Figure 1; P = 0.27). Level of supplement was not statistically significant (P = 0.20), cattle fed field peas at 0.4 or 0.8% of BW gained 2.13 and 2.15 lbs/d, respectively. Cattle fed DDGS gained 2.25 and 2.51 lbs/d for the 0.4 and 0.8% of BW levels, respectively. There was a significant difference in ADG due to type of supplement (P = 0.03). Field pea supplemented heifers had 10% lower ADG compared to DDGS supplemented heifers at 2.14 and 2.38 lbs/d respectively.

Economic Analysis

Economically, the difference in heifer performance means that if corn is priced at or $124.58/ ton of dry matter (DM), and DDGS is priced similar to corn, a producer could pay $112.13/ ton DM, or $2.89/ bu, for field peas. Depending on the price of corn (Table 1) the price a producer can afford to pay for field peas will vary when DDGS is priced similar to the corn. Currently field peas are entering human consumption markets at $6.50/bu. However, the price per bushel calculated above does not include the trucking costs of either the DDGS or the field peas. Assuming DDGS is being hauled at $3/loaded mile and peas do not require any trucking, the economics of supplementing using peas becomes much more relevant. If a producer is paying for

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Table 1. Economic value of field peas compared to dried distillers grains plus solubles (DDGS)

Corn \$/bu (56 lb)	DDGS[1] \$/ton DM	Field Pea \$/bu (60 lb)[2]
3.00	124.58	2.89
3.50	145.35	3.38
4.00	166.11	3.86
4.50	186.88	4.34
5.00	207.64	4.82

[1] DDGS = dry distillers grains plus solubles; prices shown are equivalent to corn price

[2] Equivalent price for field peas given a 10% reduction in ADG compared to DDGS

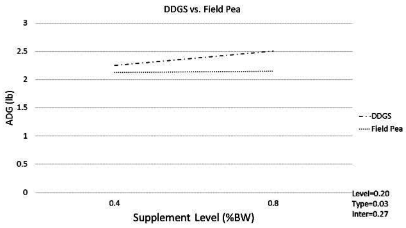

Figure 1. Average daily gain (ADG) of growing heifers supplemented with 0.4 or 0.8% of body weight with distillers grains plus solubles (DDGS) or field peas

distillers that is priced equally to \$3.00/bu corn they could only afford to haul their distillers approximately 250 miles at \$3.00/loaded mile before it became more economical to feed locally sourced field peas.

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Effect of Rapeseed Inclusion in Late-Summer Planted Oats Pasture on Growing Performance of Beef Steers

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Summary with Implications

Fall cover crops have been shown to be an effective way to background calves into the winter. An oat monoculture was planted in late summer at 100 lb/ac and compared to oats planted at 50 lb/ac with rapeseed included at 3 lb/ac. Initial forage yield was not affected by the inclusion of rapeseed with fall oat. Calf gain tended to be greater and cost of gain was decreased when rapeseed was included. Including rapeseed in late summer planted oats may be beneficial for producers who want to graze growing calves in the fall.

Introduction

Producers in Nebraska have significant opportunity to grow spring born calves during the fall and early winter on forages, such as cover crops, produced on cropland. Oats and brassicas (turnips and radishes) planted in mid to late-August after winter wheat harvest or early corn silage harvest have been shown to maintain quality from November through January (*2018 Nebraska Beef Cattle Report*, pp. 60–62). The energy content of the oat and brassica remained high into January even though the forage appeared low in quality. The digestibility of the brassica was especially high and appeared to be more nutritionally similar to a concentrate than forage. Previous work has shown that energy supplementation on high quality forages such as wheat pasture can improve gain of growing calves. Therefore, the greater digestibility (i.e., energy) of the brassica may improve calf gain compared to grazing oats forage alone. Additionally, the seed costs for brassicas are lower than oats. The purpose of this study was to evaluate the inclusion of a brassica (rapeseed) with late summer planted oats and the effect on forage yield, forage quality, and growing calf gain. We hypothesized that forage yield of the oats-rapeseed mix would be similar to the oats monoculture and that growing calf performance would be improved. Therefore, the decreased seed cost of the oats-rapeseed mix would be beneficial for producers grazing cover crops in the fall because the cost of gain would be reduced.

Procedure

This 2-year study was conducted at the US Meat Animal Research Center near Clay Center, Nebraska. Following corn silage harvest or alfalfa termination, three irrigated pivots (one in year 1 and two in year 2) were divided into four quarters. Pivots were planted on August 24 in yr 1 and August 31 and September 1 in yr 2. Two quarters from each pivot were planted with 100 lb/ac oat seed (*Avena sativa*; OAT) while the other two quarters were planted with 50 lb/ac oat seed and 3 lb/ac rapeseed (*Brassica napus*; MIX).

Pivots were grazed by one-hundred and twenty spring born cross-bred steers in year 1 and two-hundred and forty in year 2. Steers were weaned and placed into drylot on a corn silage based grower ration until late October where they were weighed in the morning prior to feeding. Steers were weighed and were stratified by initial BW (583 lb.; SEM= 8.4 in year 1 and 637 lb.; SEM =6.0 in year 2) and assigned to treatment and replicate (30 steers/ 30 acre quarter). Steers were turned out to graze on November 1 in year 1 and November 13 in year 2 and grazed until forage appeared to be limiting in one quarter, with approximately 3 inches of growth remaining. Steers grazed until February 7 in year 1 (99 days) and January 23 (71 days) in year 2. Steers were weighed the morning they were pulled off of pivots.

Forage quality and biomass samples were taken prior to grazing, monthly throughout the grazing period, and post grazing. Oat and rapeseed were clipped to ground level and immediately put on ice and froze for at least 24 hours before drying in a 60° C oven. Samples were ground to a 1 mm particle size through a Wiley mill. Nutrient analysis was conducted to evaluate organic matter (OM, % of DM), crude protein (CP, % of DM) and in-vitro organic matter digestibility (IVOMD, % of OM).

A partial budget analysis was conducted to evaluate the establishment costs of each forage treatment. Seed costs for OAT was $25/ac while cost of seed for MIX was $15.50. Seeding costs and fencing costs were the same for all pivots at $15/ac and $5/ac, respectively. Fertilizer and irrigation amounts were different among pivots and were charged using N cost of $0.42 /lb N and $4.23/acre-inch of irrigation. Pivot 1 in yr 1 was irrigated with 3.8 inches while pivots 2 and 3 in yr 2 received 2.6 inches. Pivot 1 had no fertilizer applied while pivot 2 received 15.6 lb N/ac and pivot 3 received 31.5 lb N/ac. Total costs per acre were estimated to be $59.33/ac for OAT and $54.83/ac for MIX.

Results

Initial yield did not differ ($P = 0.59$; SEM = 567; Table 1) among the OAT and MIX treatments with 3,371 and 3,221 lb/ac, respectively. However, post grazing biomass tended ($P = 0.09$; SEM=106 lb/ac) to be greater for the OAT (1,553 lb/ac) than MIX (1,317 lb/ac).

The initial proportion of the MIX was 73% oat and 27% rapeseed on a DM basis. Overall CP and IVOMD, for OAT was 12.9% and 68.7%. The overall rapeseed itself was 20.3 ± 5.6% CP and 73.9 ± 11.4 % IVOMD. Including the rapeseed into the MIX increased ($P = 0.02$; SEM =0.71; Table 1) CP to 15.5% compared to OAT at 12.9%; although not significant, IVOMD tended

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Table 1. Forage Yield and Quality

	OAT	MIX	SEM[1]	*P*-value
Pre-grazing yield, lb/ac	3,371	3,221	567	0.59
Post-grazing yield, lb/ac	1,553	1,317	106	0.09
IVOMD[2], % OM	68.7	71.4	0.01	0.07
CP, % DM	12.9	15.5	0.71	0.02

[1]Standard error of the least square mean

[2]IVOMD = In vitro organic matter digestibility a proxy for energy content

Table 2. Growing performance

	OAT	MIX	SEM[1]	*P*-value
Initial BW, lb	608	611	5.83	0.49
ADG, lb	1.95	2.11	0.08	0.07
Cost of gain[2] $/lb	0.38	0.33	0.03	0.01

[1]Standard error of the least square mean

[2]Cost of gain includes seed costs at $25 /ac for oats or $15.50/ac for mix, plus seeding costs at $15/ac, fertilizer $6.59/ac, irrigation $12.73/ac and fencing at $5/ac. No yardage cost was included.

to be greater (*P* = 0.07; SEM = 0.01) for the MIX treatment compared to OAT at 71.4% and 68.7%, respectively. Initial BW did not differ (*P* = 0.49) among the OAT or MIX treatments. Steers tended (*P* = 0.07; SEM = 0.08; Table 2) to gain less grazing OAT (1.95 lb/d) than MIX (2.11 lb/d). The slightly lesser gain and greater seed cost resulted in the cost of gain being greater (*P* = 0.01; SEM = 0.03; Table 2) for OAT ($0.38/lb) than MIX ($0.33/lb).

Conclusion

Planting rapeseed at 3 lb/ac in with 50 lb/ac of oats seed in late summer produced yield in November that was similar to an oat monoculture planted at 100 lb/ac. Including rapeseed in with late summer planted oats increased the CP content and tended to increase the digestibility of the available forage which appeared to result in greater gain for calves grazing the oat-rapeseed mix. Additionally, seed cost was less for the oat-rapeseed mix resulting in a $0.05/lb decrease in cost of gain compared to oats alone. Including rapeseed in with late summer planted oats may be beneficial for producers who want to graze growing calves into the fall.

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The Effect of Varying Oat-Pea Seeding Rates on Forage Quality and Quantity

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Summary with Implications

Variable oat-pea seeding rates were evaluated to determine the effects of seeding rate on forage quality and quantity across a precipitation gradient from western to eastern Nebraska. The first year of data collected in the spring of 2017 from sites in Lincoln, North Platte, and Sidney, NE are reported here. Total forage production was greatest at the Lincoln site and did not show significant differences in forage yield between seeding rates. At the other locations, total production was greatest when mixtures were seeded with at least 35 lbs. per acre of oat (Avena sativa L.). Percent crude protein was greatest with the pea (Pisium sativa L.) monoculture and with at least 52.5 or 35 lbs. of peas per acre in Lincoln and North Platte, respectively. However, at the driest site in Sidney, no differences were detected for crude protein or total digestible nutrients between all the seeded mixtures. It is beneficial for producers to understand how forage responds under different environmental conditions and what level of forage quality will meet their livestock needs so they can economically utilize the best oat-pea mixture ratio for their location.

Introduction

A main goal when integrating crop and livestock systems is to economically produce a forage crop that meets the needs of the livestock producer. Oat-pea mixtures are cool-season annual forages that are used across a wide variety of climate conditions to maximize forage production of oats with the potential to improve forage quality, and possibly add nitrogen fixing benefits, from the forage peas. However, the addition of pea to a mixture can increase the cost of seed (Oat seed = \$0.28 to \$0.31 vs Pea seed = \$0.39 per pound). Previous research has shown that the seeding ratios of these mixtures can be manipulated to alter the quantity and quality of feedstuff being produced. Although, it is less understood how different seeding rates respond to different environmental conditions. Mean spring precipitation (March to June) is important for cool-season grass production and varies from a mean of about 8.7 inches in western NE to 13.3 inches in eastern Nebraska. The objective of this research project was to compare variable seeding rates of oats and peas across Nebraska's precipitation gradient from west to east to determine which mixture provides the greatest quantity and quality at each location.

Procedure

The study began in 2017 with research plots in western Nebraska (i.e., Sidney), central Nebraska (i.e., North Platte), and eastern Nebraska (i.e., Lincoln). At each location five different oat-pea seeding rates were planted into plots measuring 5 feet by 30 feet using a randomized block design with 4 replications. Seeding rate treatments used include *0% Oats* (0 lbs. · ac^{-1} Jerry Oat / 70 lbs. · ac^{-1} Spring Forage Pea 4010), *25% Oats* (17.5 lbs. · ac^{-1} Oat/52.5 lbs. · ac^{-1} Pea), *50% Oats* (35 lbs. · ac^{-1} Oat/35 lbs. · ac^{-1} Pea), *75% Oats* (52.5 lbs. · ac^{-1} Oat/17.5 lbs. · ac^{-1} Pea), and *100% Oats* (70 lbs. · ac^{-1} Oat/ 0 lbs. · ac^{-1} Pea). Planting dates were 04/06/2017 in Sidney, 04/06/2017 in North Platte, and 03/27/2017 in Lincoln. All plots were fertilized with 60 lbs. of nitrogen and 30 lbs. of phosphorus approximately 1 month after the plantings occurred at each location. Plots were harvested in early to mid-June at the approximate soft dough stage of the oat (Sidney = June 19, North Platte = June 19, Lincoln = June 7). Samples were hand-clipped and separated to determine the proportion of the mixture that was oats and peas for each seeding rate treatment. To determine total production, the plots were harvested at a stubble height of 4 inches using a carter forage harvester. All production samples were oven dried to a constant weight and results are reported on a dry matter basis.

Grab samples were then taken from the harvested material and analyzed using a wet chemistry analysis by Ward Labs to determine crude protein (CP) and total digestible nutrients (TDN). March through June precipitation was 7.2 inches in Sidney, 7.1 inches in North Platte, and 18.8 inches in Lincoln. Due to abnormally dry conditions in late May and June in North Platte 3.3 inches of water was applied through irrigation for a total of 10.4 inches (irrigation plus rainfall from March to June). Different seeding rates were compared at each location using a mixed model analysis of variance in SAS.

Results

In 2017, total forage production of the seeding rate treatments differed ($P < 0.05$) at the western and central locations, but not at the eastern site ($P < 0.70$). The monoculture of oats in Sidney and the 75% oat mixture in North Platte had the greatest amount of total forage production at their respective locations, but these treatments were only statistically different from treatments with 0% and 25% oats at each location. In Sidney, total forage production from the 100% oat treatment was at least 70% greater than production of mixtures with 0% and 25% oats, but not different from treatments with at least 50% oats in the seeding rate. At the Lincoln location, the mixtures showed no statistical differences in production, but the highest yielding was the 50% oat mixture. The monoculture of peas produced the least amount of forage at all three locations, but was only statistically different from the 75% oat mixture in North Platte and the 100% oat mixture in Sidney (Table 1).

Crude protein at the central and eastern

Table 1. Comparison of production, total digestible nutrients, and crude protein of oat and pea mixtures planted at different seeding rates at 3 locations in Nebraska

		Seeding Rate Treatments (lbs. * ac^{-1})											
Study location		Oat 0# pea 70#		Oat 17.5# pea 52.5#		Oat 35# pea 35#		Oat 52.5# pea 17.5#		Oat 70# pea 0#		SE	P-value
Lincoln													
Total production	(lbs · ac^{-1})	7202		7220		8866		8162		7811		1028	0.70
Oat production	(lbs · ac^{-1})	0	C[1]	4579	B	7439	A	7842	A	7811	A	900	<0.01
Pea production	(lbs · ac^{-1})	7202	A	2641	B	1426	B	320	C	0	D	485	<0.01
TDN	(%)	50		51		49		51		50		2	0.86
	(lbs · ac^{-1})	3559		3708		4288		4174		3848		416	0.62
Crude protein	(%)	20	A	18	AB	15	BC	14	BC	11	C	2	0.03
	(lbs · ac^{-1})	1447	A	1321	A	1246	A	1109	AB	825	B	117	0.04
North Platte													
Total production	(lbs · ac^{-1})	4387	B	5002	B	6280	AB	6430	A	5440	AB	448	0.03
Oat production	(lbs · ac^{-1})	0	D	1162	C	4153	A	4801	AB	5440	A	338	<0.01
Pea production	(lbs · ac^{-1})	4387	A	3840	A	2127	B	1628	B	0	C	430	<0.01
TDN	(%)	58		57		58		59		57		1	0.77
	(lbs · ac^{-1})	2529	B	2822	B	3625	A	3763	A	3112	AB	277	0.02
Crude protein	(%)	19	A	17	A	18	A	14	B	9	C	1	<0.01
	(lbs · ac^{-1})	835	B	869	B	1164	A	900	AB	488	C	105	<0.01
Sidney													
Total production	(lbs · ac^{-1})	1932	B	2016	B	2581	AB	2826	AB	3430	A	340	0.05
Oat production	(lbs · ac^{-1})	0	D	1544	C	2146	BC	2606	AB	3430	A	307	<0.01
Pea production	(lbs · ac^{-1})	1932	A	472	B	434	B	220	B	0	C	137	<0.01
TDN	(%)	55		-[2]		57		57		55		2	0.46
	(lbs · ac^{-1})	1059	C	-		1356	BC	1592	AB	1803	A	125	<0.01
Crude protein	(%)	20		-		17		17		16		2	0.27
	(lbs · ac^{-1})	383		-		420		483		536		52	0.06

[1](a,b,c,d) Different letters within a row represent significant ($P < 0.05$) difference between the seeding rates

[2]Forage quality data was not analyzed at the Sidney site for the treatment Oat 17.5#/Pea 52.5# because of lost samples

sites typically followed the expected pattern of decreasing CP as the proportion of pea in the treatments decreased, but at the western location CP was not different between the different seeding rate treatments. At the central location, treatments of 0%, 25%, and 50% oats produced the greatest percent CP while in Lincoln it was treatments with 0% and 25% oats.

Total CP production was calculated as the total lbs. · ac^{-1} to determine what mixtures had the greatest amount of CP available based on the amount of forage produced. Again, the central and eastern location showed significant differences with reduced pea seeding rates. The treatment of 100% oat produced the lowest production of CP on a per acre basis at both the central and east location. No differences were detected in total CP across the treatments at the western site. At the central location treatments with 50% and 75% oats produced the greatest total CP production while treatments with 0%, 25%, 50%, and 75% oats performed best in the east. No significant differences ($P > 0.05$) were found for TDN between the 5 seeding ratios at any of the 3 locations. Estimated seed costs for planting a pea monoculture were $27 per acre (70 lbs. of pea at $0.39 per lb.), the 50% oat mixture seed costs were $24 per acre, and the oat monoculture seed costs were the cheapest at around $20 per acre.

Conclusion

It is important for producers to know the quality needs of the livestock utilizing the forage, which should factor into mixture selection. It would not be beneficial for a producer to grow a higher quality feedstuff than what the animal needs because the extra quality would go unutilized. Adding pea up to half of the seeding rate did not negatively affect total production at all of the locations. At the eastern location, at least half of the seeding rate in pea was needed to increase CP in the forage compared to the oat monoculture. At the central location, adding only 17.5 lbs. of pea seed to the mixture increased the total available crude protein compared to oats alone. At the western site, planting only oats provided the greatest production without a large reduction in forage quality compared to the rest of the treatments. For producers in central and eastern Nebraska, planting an oat-pea mixture with 25 to 50% peas typically provided comparable production to only planting oat, but with greater crude protein levels. While more research is needed in drier conditions of western NE, planting an oat monoculture may optimize production while still maintaining relatively good crude protein levels compared to oat-pea mixtures. According to year 1 data, if a producer is only focused on biomass production it would be beneficial to plant an oat monoculture to save money on seed cost while maximizing forage production.

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Nitrate Concentrations of Annual Forages Grown for Grazing in Nebraska

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Summary with Implications

Annual forage samples sent by producers to Ward Laboratories Inc. for nitrate analysis were evaluated to determine which cover crop species in Nebraska are most likely to accumulate nitrates, and how often the accumulated nitrates are considered toxic by traditional recommendations. Additionally, nitrate levels of cover crop mixes grown in research trials were analyzed to ensure species differences were repeated when grown together in the same fields. Brassicas accumulate more nitrate than small grains, millet, sorghum/sudan grasses, or cover crop mixes. Brassicas accumulated levels of nitrate considered moderately to highly toxic in 48% of the samples. The other cover crop species accumulated potentially toxic nitrate levels in 20–28% of the samples. However, when cattle graze these forages, there are multiple factors that may mitigate toxicity. Cattle have grazed annual forages containing nitrate concentrations considered toxic, and no adverse health consequences were observed. More research is needed to reevaluate the risk of nitrate toxicity when grazing cover crops.

Introduction

Nitrate toxicity has long been recognized in ruminant animals and general guidelines indicating threshold nitrate concentrations were developed in the 1940s and 1960s to advise producers on what levels of nitrate could be fed before becoming detrimental. Cover crops are frequently grazed by producers, but these forages often test high in nitrate, and a producer must then decide what course of action will be taken. The goal of this study was to determine which cover crop species grown in Nebraska are most prone to accumulating high nitrate concentrations, as well as how often these species would be considered toxic when using traditional guidelines.

Procedure

This experiment included a collaboration with Ward Laboratories Inc. (Kearney, NE). Fresh annual forage samples (n=443), that were sent by producers to Ward Laboratories for nitrate analysis and contained less than 26% DM (mean=18.2% SD ± 4.6%) during 2016–2017 were summarized to determine which forages accumulated the most nitrate-nitrogen (NO_3-N), and how often these forages accumulated nitrate considered toxic by traditional recommendations. The samples were classified into five species groups 1) brassica (turnip, radish, collard; n=63), 2) mix (cover crop mix or multiple annual forage species; n=34), 3) small grain (oat, rye, triticale, wheat, barley; n=70), 4) millet (pearl, foxtail, German; n=40), or 5) sorghum/sudan (cane, sorghum, sudangrass; n=236). These samples were analyzed to evaluate species differences in average nitrate accumulation. Each species category was also sorted to determine what proportion of the samples in each species category would fall into the traditional nitrate toxicity recommendations 1) Safe (<1400 ppm NO_3-N DM), 2) Marginal (1400–2100 ppm NO_3-N DM), 3) Caution (2100–5000 ppm NO_3-N DM), 4) Toxic (>5000 ppm NO_3-N DM).

Additionally, six fields planted to a small grain brassica mix in late summer were sampled in late fall to evaluate how species accumulation differs when grown under identical conditions. These mixtures included oats or rye planted with turnips and/or radishes. Samples were obtained by randomly selecting individual species throughout the field, clipping small grains at ground level, and pulling the whole brassica plant up and separating the top from the roots. All samples were dried in a 140 °F forced air oven and ground to a 1 mm particle size in a Wiley mill. Lab analysis was done to determine ppm nitrate-nitrogen on a dry matter basis (ppm NO_3-N DM) using a nitrate ion selective electrode. One gram of dried, ground sample was continuously mixed in 40 ml of pH 7 water at room temperature with a rocker for 30 minutes before measuring. A standard line with known nitrate standards was used to calibrate the electrode prior to sample analysis.

Results

From the commercial lab dataset, there was a significant effect of species on nitrate accumulation ($P < 0.01$). Brassicas contained the most ($P < 0.01$) nitrate with an average of 4060 ppm NO_3-N. The cover crop mix (1806 ppm NO_3-N), sorghum/sudan (1564 ppm NO_3-N), millet (1391 ppm NO_3-N), and small grains (1008 ppm NO_3-N) did not differ ($P > 0.05$) although there was a slight tendency for the cover crop mixes to contain more nitrates than small grains ($P = 0.10$).

The six field collections with small grain and brassica mixes grown agreed with the dataset from the commercial laboratory. Small grains (161 ppm NO_3-N) contained less nitrate than brassicas ($P < 0.01$). Radish tops (9248 ppm NO_3-N), radish roots (9073 ppm NO_3-N), turnip roots (6354 ppm NO_3-N), and turnip tops (5932 ppm NO_3-N) did not differ in nitrate content. However, there was a tendency for radish tops to contain more nitrate than turnip tops ($P = 0.06$) and turnip roots ($P = 0.10$), as well as a tendency for radish roots to contain more nitrate than turnip tops ($P = 0.07$).

Figure 1 illustrates how often each species category from the commercial lab dataset would be considered safe, marginally safe, fed with caution, and toxic. Brassicas exceeded the caution threshold in 48% of samples and were 5 times more likely ($P < 0.01$) to be above this threshold than any of the other species categories. The other species did not differ in the frequency they

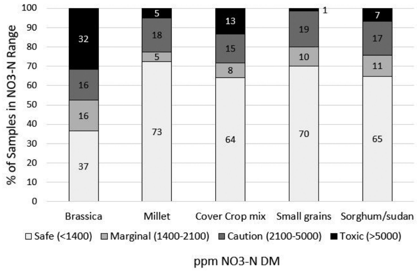

Figure 1. Species distribution of samples in NO_3-N risk of toxicity categories.

Table 1. Example annual forage trials with average nitrate-nitrogen concentrations

Forage Type	NO_3-N, ppm	Sex	Year	ADG (lb./d)
Oat, Turnip, Radish mix	6146	Steers	2014	2.2
Oat, Turnip, Radish mix	4655	Steers	2015	1.3
Oat, Turnip, Radish mix	2158	Heifers	2015	1.6
Oats (Hill)	912	Steers	2015	1.1
Oats (Valley)	4414	Steers	2015	1.5
Oats (Hill)	3921	Steers	2016	2.3
Oats (Valley)	8026	Steers	2016	2.5

[1]Oats sampled to ground level

[2]Brassicas sampled by harvesting the entire plant and separating the top from the root

[3]Traditional guidelines would consider NO_3-N concentrations >2100 as moderately toxic and >5000 as toxic

would fall into the caution and toxic categories ($P > 0.05$). The other species ranged from 20–28% of the samples falling into the caution or toxic categories, indicating that there is still a high likelihood that these annual forage samples could be considered toxic using traditional guidelines.

Although the nitrate concentrations in these forages frequently exceed what traditionally would be considered toxic, the signs of nitrate toxicity are not always present when grazed. The traditional guidelines were developed in trials feeding high nitrate hay, or supplemental nitrate salts given through a stomach tube or top dressed onto feed, resulting in guidelines that are not reflective of cattle grazing annual forages. Table 1 provides examples of seven different grazed cover crop paddocks with varying levels of nitrate in the forage. In these examples, weaned calves grazing these forages had no observable signs of nitrate toxicity even though the nitrate concentrations often exceeded traditional guidelines. When grazing, multiple factors may provide some mitigation that allow the cattle to graze high nitrate forages without adverse health consequences. If cattle are not forced, they tend to graze the leaf and top parts of the plant first which are lower in nitrate than the stem, with the lower part of the stem having the most nitrate. Thus, grazing at stocking rates that allow for selectivity and self-adaptation (grazing lower nitrate plant parts and working down the plant) can reduce toxicity potential. Some other mitigation factors include a high-quality diet (more energy for bacteria in the rumen to use the nitrite), fresh forages releasing nitrate in the rumen at a slower rate than dry forages, and a slower rate of intake when grazing rather than consuming hay.

Conclusion

When utilizing annual forages as a feed resource, it is important to be aware of the risk of nitrate accumulation. If utilizing brassicas as a forage, understand that these species frequently accumulate high levels of nitrate and utilizing a grass in the mix may be recommended as the grass will keep brassicas from being 100% of the diet. However, forages that exceed traditional "toxic" recommendations have been grazed without consequence. Future research is needed to reevaluate the toxic level of nitrate in grazed annual forages before better recommendations can be made.

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Impact of Grazing Spring Rye on Subsequent Crop Yields and Profitability

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Summary with Implications

Steers (729 ± 19 lb BW) grazed in two November-planted cereal rye fields for 22 d in April, either with or without an ionophore in their free choice mineral supplement. Subsequent corn yields were measured to assess impact of planting cereal rye as a cover crop (not grazed) or grazing the rye compared to a no rye control. There was no statistical impact of rye or grazing on subsequent corn yield. Supplying an ionophore in the mineral did not uniformly improve gains across fields. However, gains were high at 3.2 lb/d and were able to offset the cost of planting rye.

Introduction

Incorporation of cover crops into traditional cropping systems has been shown to provide numerous agronomic benefits, including improved soil organic matter, reduced nutrient runoff, and weed suppression. Producers could also benefit from added economic diversity by integrating cattle into this production system by grazing the cover crop. Cereal rye is commonly utilized as a cover crop, but little work has been done on the incorporation of grazing late fall planted rye in the spring in Nebraska. The spring grazing potential of late fall planted rye including animal performance, duration of grazing and economics as well as the impacts on subsequent cash crop yields are not well known. Different cattle management strategies also have the potential to improve the economics and performance of the system, such as providing ionophore to grazing cattle, which has been shown to improve ADG and reduce bloat in cattle grazing wheat pasture, but this has not been extensively studied in cereal rye pastures. The objective of this study was to assess the impacts of incorporating rye with and without grazing on subsequent crop yield, and test ionophore supplementation through a free choice mineral on growing calf performance while grazing rye.

Procedure

Two fields averaging 103 ac each near Mead, NE, were separated into three blocks with each block containing four treatments: a negative control strip (120 ft wide) not planted with cereal rye (5.5 ± 1.6 ac), a positive control strip (120 ft wide) planted with cereal rye but not grazed (5.1 ± 1.5 ac), and two pastures (10.2 ± 3.0 ac) planted with rye and grazed. Cattle in one pasture were provided free choice trace mineral supplement without a monensin ionophore, and the other pasture provided a mineral with monensin ionophore (4 oz target intake to supply 200 mg/h/d), resulting in a total of 3 replications per treatment in each field. Field 1 was in a corn-soybean-wheat crop rotation, with the most recent harvest being wheat harvested in July of 2016, followed by a hay crop of sorghum-sudan grass, which was swathed on September 26, 2016 and baled after approximately 2 weeks of drying in October. Field 2 was in a corn-soybean rotation, with the most recent harvest being soybeans harvested on October 18, 2016. Elbon cereal rye was planted on October 28, 2016 at a rate of 70 lb/ac, and fertilized with 11–52–0 at a rate of 40 lb N/ac on November 15, 2016.

On April 4, 2017, 184 commercial crossbred steers (729 ± 19 lb BW) were turned out for grazing when rye had reached approximately 4 to 5 inches of growth. Prior to turn out, cattle were limit fed for 7 days on a diet of 50% Sweet Bran and 50% alfalfa hay (on DM basis), and three day empty body weights were taken to assign cattle to pastures. Based on rye biomass production, Field 1 was stocked at a rate of 0.9 hd/ac and Field 2 was stocked at a rate of 1.8 hd/ac. Cattle grazed for a total of 22 days, with two pastures having half the number of cattle removed at 14 d due to low forage availability. Cattle were limit fed at the end of the trial for 5 days on the same diet as stated previously to equalize gut fill, and three day BW were taken. Weights were adjusted to account for 1 lb/d gain during the limit fed periods. During the grazing period, mineral disappearance was measured by weighing feeder tubs weekly and taking samples for dry matter adjustment.

Stand counts for corn plants were collected in mid-June when corn had reached approximately V6-V8 stage of growth (six to eight visible above-ground leaves). Three sampling points within each treatment in each block were randomly selected across the field. At each sampling point, the number of corn plants within a 17.5 ft length of row was counted for three adjacent rows, resulting in an average for each sampling point. Corn yields were measured using hand harvest methods when corn had reached black layer formation (Oct 9th, 2017). Three locations in each treatment within each block were selected, and a 17.5’ length of row was hand harvested, where corn ears had the husk removed and a total ear weight was obtained in the field. Three randomly selected ears were also weighed separately and retained for DM analysis. Ears were dried and kernels removed from the cob, and both parts were dried in a 140° F forced air oven for 48 h, where dry weights were used to calculate the proportion of kernel to cob, and DM yield estimate for corn grain. Data presented were adjusted to 85% moisture bushel yields.

Economics were evaluated by conducting a partial budget analysis. Rye seed cost was budgeted at $16.80/ac, fertilizer cost at $10.00/ac, custom drilling at $13.36/ac and fertilizer at application costs of $6.00/ac. Cattle costs included fencing at $4.40/ac, mineral costs of $0.07/hd/d for control and $0.08/hd/d for ionophore, and $0.10/hd/d for yardage costs.

Data were analyzed using the MIXED

Table 1. Results of corn yield, corn plant population, and cattle performance and economics from the first year of planting and grazing cereal rye over 22 days in the spring with and without an ionophore supplement.

	Grazed Control	Grazed Ionophore	No-graze, Rye	No Rye	SEM	*P-value*
Stand count-early, plants/ac	31,370^{b}	32,463^{ab}	33,667^{a}	32,296^{b}	442	0.02
Stand count-harvest, plants/ac	31,167^{b}	33,556^{b}	35,778^{a}	32,944^{b}	1201	0.10
Corn Yield, bu/ac[1]	189	203	204	211	14.1	0.59
ADG, lb	3.1	3.3	-	-	0.24	0.60
Gain per acre, lb	98.8	96.7	-	-	7.4	0.84
Returns, $/hd[2]	37.63	48.68	-	-	6.55	0.31
Returns, $/ac	62.81	70.09	-	-	8.00	0.56

[1] Due to flooding, some of Field 2 was replanted with different hybrids, thus only data from Field 1 was analyzed and reported.

[2] Seed cost of $16.80/ac, fertilizer cost of $10.00/ac, custom drilling and application costs of $13.36/ac and $6.00/ac. Cattle cost included fencing at $4.40/ac, mineral costs of $0.07/hd/d for control and $0.08/hd/d for ionophore, and $0.10/hd/d for yardage costs with calf price at $140/cwt.

procedure of SAS 9.4 (SAS Institute Inc., Cary, NC). Rye biomass, cattle performance and economic returns were analyzed with field and treatment at fixed effects and block as a random effect. Corn yield and stand count data were analyzed with treatment as a fixed effect and block as a random effect. Due to replant (due to partial flooding) with different hybrids in Field 2, only yield data from Field 1 were analyzed and reported. Mineral disappearance was analyzed with field, treatment, and week as fixed effects. Results were declared significant when $P < 0.05$ and tendencies were declared when $0.10 < P < 0.05$.

Results

Rye biomass production at the beginning of the grazing season was significantly different ($P = 0.03$) between Field 1 and 2, but not different ($P = 0.45$) between treatments. The average production at the start of grazing on March 27 was 450 lb/ac DM, but Field 1 was measured at 411 ± 20 lb/ac DM, and Field 2 was measured at 492 ± 20 lb/ac DM. Field 1 established slower, and had less biomass than Field 2 despite planting and fertilizing at the same time. This can potentially be attributed to differences in soil moisture between the two fields. Field 1 entered the study after a wheat harvest followed by a short-season crop of sorghum-sudan hay, and Field 2 entered the study after a soybean harvest. Although not measured, the additional hay crop is suspected to have had an impact on rye establishment and subsequent spring growth because it appeared there was reduced soil moisture. At the end of the grazing period, there was a significant interaction ($P < 0.01$) between fields and treatment for rye biomass production. There were no differences ($P = 0.62$) in rye biomass at the end of grazing in the two fields, with control (no ionophore) having 503 lb/ac and ionophore having 538 lb/ac. The ungrazed treatments had significantly ($P < 0.01$) more biomass with Field 1 being less ($P < 0.01$) at 776 lb/ac than Field 2 at 3596 lb/ac. The stocking rate and number of grazing days resulted in a harvest of 0.47 AUM/ac in Field 1 and 1.06 AUM/ac in Field 2.

There was a significant difference ($P = 0.02$) between treatments on corn plant populations at establishment. Ungrazed rye plots appeared to have the greatest plant populations, with no difference ($P > 0.10$) between the no-rye or grazed rye treatments. However, there was no statistical difference ($P = 0.59$) between treatments for the subsequent corn yield in 2017 (Table 1), but some numerical differences were observed. The rye was killed at planting, which may have contributed to the numerically lower corn yields in the grazed and ungrazed rye treatments.

There was no effect of treatment ($P = 0.17$) on mineral disappearance. However there was a field effect ($P < 0.01$), whereby mineral disappearance was greater in Field 2 at 6.1 oz/hd/d than Field 1 at 3.8 oz/hd/d. There was a tendency ($P = 0.06$) for an interaction between field and supplement for average daily gain (ADG). Cattle supplemented with control mineral gained 2.87 lb/d and cattle receiving ionophore gained 3.57 lb/d in Field 1, but in Field 2, control cattle gained 3.41 lb/d compared to 2.90 lb/d for the ionophore-supplemented cattle. When averaged across the 22 d grazing period, steers gained 3.2 lb/day (Table 1). Total gain per acre averaged 98 lb/ac, although there was a significant ($P < 0.01$) field effect with Field 1 averaging 60 lb/ac and Field 2 averaging 136 lb/ac. This was expected, since Field 2 produced more biomass and was stocked at nearly double the stocking rate.

The price of the calves per pound did not change during the short time period, and there was no price slide for this class of cattle sold in May 2016; the value used to calculated costs and revenue was $140/cwt. Total cost to establish the rye for this operation was $50.56/ ac for Field 1 and $50.03/ ac for Field 2. There was no significant difference ($P = 0.31$) between grazing mineral treatments in returns per head or per acre (Table 1). There was a difference ($P < 0.01$) between fields, due to the differences in stocking rate with Field 1 returning $32.53/ ac and Field 2 returning $111.7/ac.

Conclusions

In this study, steers demonstrated considerable growth over a short period of time, indicating that growing cattle can perform well on spring rye maintained in a vegetative state. Furthermore, no statistically negative impacts on corn yield or establishment were observed with planting and grazing rye. No consistent improvement of ADG was observed with providing an ionophore in the mineral supplement. Grazing growing calves in early spring on late fall planted cereal rye offset the costs of planting the rye and provided additional returns.

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Prediction of Energy Value (TDN) in Grazed and Hayed Forages

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Summary with Implications

The goal of producers and nutritionists is to meet the nutritional needs of their cattle. Requirements are well established, but the diets of grazing cattle are difficult to predict. Selection by the animal, sample handling, lab analysis, and relating the lab analysis to the animal are issues that have been researched the last 20 years. Based on that research, data have been compiled to predict the energy and protein values of grazed Sandhills range, meadows, smooth brome, and corn residue. Additionally, equations used by commercial labs to predict the TDN of grass hays based on ADF were compared to TDN estimates based on in vivo digestion. Predictions of TDN values from ADF varied in accuracy and need to be used with caution.

Introduction

The 1996 Nutrient Requirements for Beef Cattle (96 NRC) first recommended metabolizable protein requirements for cattle and included a computer model to predict cattle performance from dietary inputs. After the 96 NRC was released cow performance data from the Gudmundsen Sandhills Laboratory (GSL) was used to evaluate the model (*1996 Nebraska Beef Cattle Report*, pp. 10–13). A series of experiments were used to better define the nutrient values of grazed forages, so as to provide good input values for requirement models. The objective of this report is to describe the necessary adjustments and present the updated nutrient values of grazed forages.

Table 1. Acid detergent fiber and TDN content of grass hays, baled corn residue and husks used to evaluate prediction equations.

Forage	ADF, % of DM	TDN[1], % of DM
Bromegrass hay	41.0	52.9
Bromegrass hay	45.3	51.1
Prairie Hay	44.5	48.8
Meadow Hay	38.5	55.6
2 Row corn residue (King)	50.4	55.9
8 Row corn residue (King)	54.9	43.8
Conventional corn residue (King)	56.7	46.2
2 Row corn residue (Updike)	54.5	49.7
Husklage (Updike)	54.3	54.9
Husk (Updike)	44.3	65.5

[1] TDN assumed to be equal to digestible organic matter

Procedure

The energy value of the forage samples were predicted using in vitro digestion. However, in vitro digestibility values must be adjusted to obtain TDN values that could be used for diet evaluation in models. A cattle digestion study was conducted to establish actual animal digestion values (in vivo) for forages to act as standards for lab analyses (IVDMD or IVOMD; *2007 Nebraska Beef Cattle Report*, pp. 109–111). Across five different hay sources, IVDMD was 5.4 percentage units higher than in vivo digestibility. Additionally, there is variation from run- to-run within vitro digestibility. Using hay samples with known in vivo digestibility as standards for in vitro analysis allows for adjustment of in vitro values to in vivo values by accounting for both run- to-run variation and adjusting for the difference between in vivo and in vitro digestibility. It is assumed that digestible organic matter (DOM) is equivalent to TDN.

Cattle selectively graze so it is necessary to use diet samples for nutrient evaluation of grazed forages that have been collected with esophageally or ruminally fistulated cattle. Saliva from mastication contaminates the sample, and in the past, the diet samples were squeezed to remove excess moisture. Squeezing removed some highly digestible nutrients (*2013 Nebraska Beef Cattle Report*, pp. 49–50; *2015 Nebraska Beef Cattle Report*, pp. 64–65). Thus when squeezed, the IVDMD should be increased 1.8 percentage points to account for loss of highly digestible nutrients.

Diet samples of cows grazing range were collected over 3 years at GSL (*2008 Nebraska Beef Cattle Report*, pp. 18–19.). Diet samples were collected from steers grazing smooth brome at Eastern Nebraska Research and Extension Center (ENREC) over a 5 year period (*2011 Nebraska Beef Cattle Report*, pp. 24–25). The pastures were rotationally grazed so diet quality may be greater than for continuous grazing. Diet samples were collected by cows grazing wet meadows at GSL (*2010 Beef Cattle Report*, pp. 36–38; *2014 Nebraska Beef Cattle Report*, pp. 50–51). Diet samples were collected by cows or steers grazing corn residue at ENREC, near Mead, or West Central Water Resources Field Laboratory near Brule, NE (*2011 Nebraska Beef Cattle Report*, pp. 33–34; *2017 Nebraska Beef Cattle Report*, pp. 60–61).

The protein values used to evaluate the models were calculated using the crude protein values obtained by Geisert et al. (*2008 Nebraska Beef Cattle Report*, pp

18–19) and the degradability reported by Buckner et al. (2013 Journal of Animal Science 91:2812–2822) and Gigax (2011 UNL thesis). Another challenge in determining the nutrient adequacies of grazed forages is estimating animal intake. Data collected by Meyer et al. (*2009 Nebraska Beef Cattle Report*, pp. 13–14) suggest that lactating cows will consume 2.5% of body weight when fed a diet with a digestibility of 52 to 55% TDN. Dry cows consumed 2.1% of body weight while on the same forage. Data supports the use of 2% of body weight for dry cows grazing corn residue or winter range (*2012 Nebraska Beef Cattle Report*, pp. 5–7; *2012 Nebraska Beef Cattle Report*, pp. 15–16).

Most commercial labs use chemical analysis to predict TDN of submitted samples. One commonly used method is to predict the TDN of forages using the acid detergent fiber (ADF) content. While these predictions can be useful, the equation used can have significant impacts on the accuracy. The TDN prediction of six equations commonly used by commercial labs were compared to the TDN measured as DOM of four hays, five baled corn residue samples and husks obtained from hybrid seed production (Table 1). The equations were 1) TDN = 4.898+(89.796*(1.0876–0.0127*ADF)); 2) TDN = 32.4+53.1*(1.044–0.0131*ADF); 3) TDN = 87.1–0.83*ADF; 4) TDN = 97.6–0.974*ADF; 5) TDN =34.9+53.1*(1.085–0.015*ADF); 6) TDN =71.7–0.49*ADF.

Results

The TDN and protein values for Sandhills range are shown in Table 2 by month and by grazing season, summer or winter. These data are consistent with cow performance at GSL (*2010 Nebraska Beef Cattle Report*, pp. 5–7; *2012 Nebraska Beef Cattle Report*, pp. 15–16). Values for smooth brome are in Table 3. Values are available only for summer months. These data are consistent with cow performance when grazing adjacent pastures (*2015 Nebraska Beef Cattle Report*, pp. 14–15). The TDN and protein values for Sandhills meadow forage are in Table 4. Values are only available for the summer months.

Values for corn residue are in Table 5. Corn residue is unique because the plant is dormant and the cattle are selective, grazing grain and husks followed by leaves. The husks are much more digestible than the leaves, so as the grazing season progresses, the TDN declines. The season long TDN value of 51% is based on 5 years of data on cows grazing irrigated corn residue at UNL recommend rates in southeast NE (*2012 Nebraska Beef Cattle Report*, pp. 5–7).

The 1996 NRC was updated in 2016 (2016 NASEM). The energy and protein requirements remained the same as those in the 1996 NRC. The dry matter intake prediction was also maintained, however, it was suggested that the NASEM equation may underestimate dry matter intake by 3–5% for lactating cows and overestimate intake by 3–5% for dry cows. This is consistent with the Meyer et al. data (*2009 Nebraska Beef Cattle Report*, pp. 13–14). Therefore, users of either the 1996 NRC model or the 2016 NASEM model might consider increasing dry matter intake by 3–5% above the model prediction for lactating cows and decreasing it for dry cows.

The 1996 NRC model assumes all ruminally undegradable protein (RUP) is 80% digestible in the intestines. However, the data in the tables illustrate that the assumption of 80% digestibility is incorrect. The 2016 NASEM model accounts for the differences in RUP digestibility and the values in the tables are appropriate for use in that model. The values are not appropriate for the 1996 model. The values in the tables provided in this report can be adjusted by the following equations:

RDP, % DM = CP, % DM x RDP, % CP

RUP, % DM = [(CP–RDP, % DM) x RUP digestibility] ÷ 0.8

Adjusted CP (to be used in 1996 model)= RDP, % DM + RUP, % DM

RDP, % (to be used in 1996 model) = RDP, % DM ÷ adjusted CP

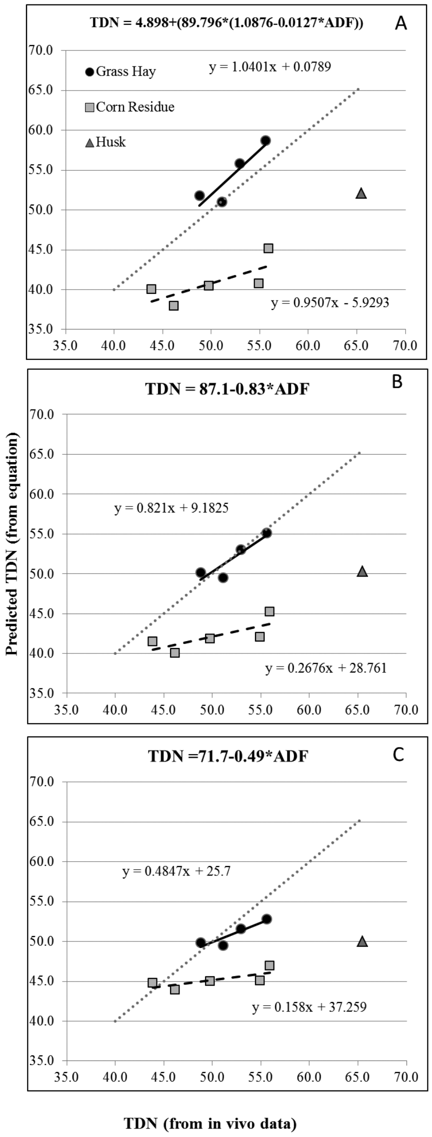

Figure 1. Prediction of TDN in hay or corn residue applying three equations based on ADF that are commonly used by commercial laboratories.

When evaluating the TDN prediction from ADF it appears that most of the equations over-predicted the energy value of the hays and undervalued the corn residue and husks. Corn husks are unique and the values were not included in the prediction equations for the corn residues. Husks are much more digestible than the ADF content would predict. The husks have excellent TDN values when consumed by grazing cattle or when husks are maximized in harvested residue. Laboratory values using ADF to determine energy content will not be accurate and significantly underestimate the TDN. None of the equations accurately predicted the TDN values of either the conventional forages or the corn residues. Three examples are illustrated in Figure 1. In panel A, the equation provided good linear relationships of TDN predicted from ADF to TDN measured in cattle in both the 4 hays and the corn residues (slopes of 1.04 and 0.95). However, the hay TDN values were about 2 percentage units too high and the corn residue values were over 9 percentage units too low.

Table 2. Sandhills range

Month	TDN, % of DM	CP, % of DM	RDP, % of CP	RUP digest,[1] %
May	64.8	12.4	84.8	38.6
June	59.9	10.8	81.5	34.6
July	55.8	9.5	83.7	20.0
August	55.2	8.9	64.0	9.5
September	50.7	8.8	70.0	11.7
October	50.3	7.9	68.4	12.0
November	48.7	7.6	67.1	12.0
December	48.6	7.0	64.3	12.0
January	51.5	6.9	63.8	12.0
February	51.9	6.2	60.0	12.0
March	49.9	7.4	66.2	12.0
April	56.8	8.0	68.9	12.0
Season, Summer[2]	57.0	10.1	76.8	22.9
Season, Winter[3]	50.2	7.2	65.0	12.0

[1] RUP digestibility, % of RUP

[2] May thru Sept average

[3] Oct thru March average

Table 3. Brome

Month	TDN, % of DM	CP, % of DM	RDP, % of CP	RUP digest.[1], %
May	68.9	18.6	85.6	50.2
June	61.7	13.7	88.3	48.3
July	58.8	13.7	86.9	46.8
August	56.3	15.3	86.8	41.7
September	52.5	15.5	85.9	39.0
Season	59.6	15.4	86.7	45.2

[1] RUP digestibility, % of RUP

Table 4. Meadow grazing

Month	TDN, % of DM	CP, % of DM	RDP, % of CP	RUP digest.[1], %
May	66.2	14.6	93.2	45.0
June	62.7	11.4	85.3	47.0
July	59.0	8.6	80.8	38.7
August	55.1	8.4	79.6	35.0
September	52.2	8.5	80.0	35.0
Season Average	59.0	10.3	83.8	40.1

[1] RUP digestibility, % of RUP

Table 5. Corn residue grazing

	TDN, % of DM	CP, % of DM	RDP, % of CP	RUP digest.[1], %
Season	51	4.61	74.5	25.6
Initial	58.3			
End	43.7			

[1] RUP digestibility, % of RUP

The equation used in panel B predicts the TDN of the hays fairly accurately within the range of 47 to 57% TDN. Because the slope is less than one (0.76), values outside the above range will not be accurate as it will over predict the digestibility of low quality hays and under predict higher quality hays. Values for the corn residues were 8 percentage units below in vivo values.

Panel C illustrates the values for an equation which was developed for straw and is sometimes used for corn residue. While the predictions for corn residues were closer than some of the others, on average 5% below in-vivo values. However, the equation did not account well for changes in TDN within corn residue (slope 0.16) that was due to differences in harvest methods. For example, conventionally baled corn residue with a 46% TDN is predicted to be 2.2 percentage units less than the in vivo value but residue with low stem content and 55% TDN is predicted to be 8.9 percentage units lower than the in vivo value. Therefore, this suggests that none of the six equations provided accurate prediction of in vivo TDN values.

Conclusions

When using diet samples and adjusting in vitro digestibility estimates, TDN could be predicted adequately. The TDN estimates provided in this report can be used to determine supplementation needs when grazing these forage resources. When ADF was used to predict the TDN of grass hay or corn residue samples, none of the six equations were accurate. Protein values provide information to estimate protein status of the cattle.

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Three Year Summary: Comparison of Diets Collected from Esophageally Fistulated Cows to Forage Quality Estimated from Fecal Analysis

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Summary with Implications

Inconsistency was found in forage quality (crude protein and energy) when esophageally fistulated diets were compared to Nutrition Balance Analyzer (NUTBAL) analysis of fecal samples. On upland range sites, hand-clipping of samples (not a recommended practice to measure forage quality), was closer to fistulated diets than NUTBAL analysis. If cattle managers are solely utilizing NUTBAL for estimates of forage value, incorrect supplemental energy and protein decisions will likely be made resulting in the purchase of unnecessary supplements, thereby reducing the profitability of the operation.

Introduction

Forage quality is difficult for beef cattle producers to measure. Researchers use fistulated animals to collect diets directly from the esophagus or rumen, but most cattlemen do not have access to fistulated animals and hand-clipped forage samples do not always reflect the selectivity of grazing animals. The Nutrition Balance Analyzer (NUTBAL) forage quality analysis method claims to measure forage crude protein and energy through the analysis of fecal samples from grazing animals collected by producers. Near Infrared Reflectance Spectroscopy (NIRS) is conducted on fecal samples and combined with client information and research/technology developed by the Grazing Animal Nutrition Lab (GAN Lab) in Temple, TX.

The objective of this study was to compare the quality estimations from forage samples collected with fistulated grazing animals, hand-clipping, and fecal samples collected for NUTBAL analysis on Nebraska Sandhills rangelands.

Procedure

Comparisons were made between forage diets collected from esophageally fistulated cows, fecal samples from cows grazing the same pasture, and from hand-clipped quadrats. The esophageal diets (forage the cow bit off, chewed, and expelled into a collection bag when swallowed) and the hand-clipped samples were evaluated for CP. Energy (TDN) was determined from ADF analysis in a commercial laboratory (Ward Labs, Kearney NE) for clipped samples, while the esophageal samples were analyzed using in vitro digestibility techniques to determine TDN. The fecal samples were evaluated for crude protein and energy (in the form of digestible organic matter [DOM]) through the NUTBAL program utilizing NIRS. Two locations were evaluated; upland pastures (warm-season grass dominated) and subirrigated wet meadows (cool-season grass dominated) at the Gudmundsen Sandhills Lab near Whitman, NE in 2016 and 2017. Hand-clipped forage samples were only collected within the upland pastures. Diet, fecal and clipped samples were collected in July, September, and November. Fecal samples were dried at 50 degree C for 72 hours prior to shipping for NUTBAL analysis.

Collections for upland pasture

Fecal samples were directly collected from 12 cows early in the months of July, September, and November 2015, 2016 and 2017. Cows were grazing upland rangeland at moderate stocking rates. Cows were in the same pasture from June to November. The cows ranged in age from 3 to 9 years old. Three esophageally fistulated cows grazed the upland pasture and diet samples were collected, at the same time the fecal samples were collected from the cows. The esophageal samples were dried, ground, and evaluated for in vitro organic matter digestibility using a 48-hour in vitro fermentation. Five standards with known in vivo digestibilities were included in the in vitro runs to correct the in vitro organic matter digestibility to in vivo digestibility. The organic matter digestibility was multiplied by organic matter content to determine digestible organic matter. Digestible organic matter was assumed to be equal to TDN for the in vitro diet sample analysis. Two in vitro runs were conducted for all samples and the in TDN estimates from the two runs were averaged. Forage was also clipped by hand in an effort to collect a sample representative of plants and plant parts consumed by cattle. This collection was subjective of the person clipping, and an attempt to estimate and collect the cows' grazing habits. The hand-clipped samples were sent to a commercial laboratory and TDN was estimated using equations from ADF content.

Collections for subirrigated meadow

Fecal samples were directly collected from 12 cows in early in the months of July, September, and November of 2015, 2016, and 2017 grazing subirrigated meadow. Three esophageally fistulated cows grazed the meadow pasture and diets were collected, the same time the fecal samples were collected from the cows. The meadows were broken into 4 pastures. The rotation allowed each pasture to be grazed twice in the growing season. Esophageal samples were analyzed using in vitro digestibility techniques and TDN was estimated in the same manner as the upland pasture samples.

Assumptions

Several assumptions were made, including: 1) the models used in the NUTBAL program represented similar forage quality

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and values as native Sandhills grassland in Nebraska. 2) fistulated animals were selecting the same diets as the grazing cows.

Other considerations included: 1) To minimize the loss of nitrogen from the manure (cow patty on the ground), fecal samples were taken directly from the cow's rectum while restrained in a cattle handling facility. 2) Total digestible nutrients reported for fecal samples were calculated from the NUTBAL energy DOM. NUTBAL DOM was converted to TDN by multiplying the DOM value reported by the GAN lab by 1.06., as suggested by NRCS Enhancement Activity 65 in 2015. 3) Precipitation received during growing season could have influenced protein and TDN in the grazed forage.

Statistical Analysis

Data were analyzed using the Mixed Procedure in SAS with sample collection method, month, and the interaction of collection method and month as the fixed effects. Year was also included in the model as a random effect. Differences were considered significant when $P < 0.05$ were observed. Upland and subirrigated meadows samples were analyzed separately. Differences were considered significant when $P < 0.05$ were observed.

Results & Discussion

The CP values reported herein were from the 2015, 2016, and 2017 sampling dates while the TDN values were from the 2016 and 2017 sampling dates only. The samples collected from esophageally fistulated steers compared to NUTBAL analyzed and hand-clipped samples resulted in significantly different measures in forage quality. The in vitro TDN values reported herein are for comparison to NUTBAL analyses. Another Beef Cattle Report (*2019 Nebraska Beef Cattle Report*, pp. 50–52), has more extensive diet sample collection and analysis. That analysis includes monthly samples for range over a three-year period with 36 diet samples for each month. While the esophageally fistulated diets' TDN estimates generally agree for both reports, the data reported in the companion article provide a more robust estimate of changes in forage quality through the growing season.

Table 1. Crude protein (CP) and total digestible nutrient (TDN) content of diets collected from *upland range* by esophageally fistulated cattle compared with NUTBAL analysis of fecal samples and clipped forage

Item	Diet[1]	NUTBAL[2]	Clipped[3]	SE	*P*-value
CP					
Jul	8.0	8.0	8.0	0.3	0.99
Sep	7.1^a	5.2^c	6.1^b	0.3	< 0.01
Nov	5.4	5.2	5.2	0.3	0.92
TDN					
Jul	56.6^b	65.8^a	55.6^b	1.0	< 0.01
Sep	46.2^c	64.4^a	54.7^b	1.0	< 0.01
Nov	44.3^c	62.4^a	50.2^b	1.0	< 0.01

[1] TDN equal to digestible organic matter using in vitro organic matter digestibility.

[2] Digestible organic matter (DOM) was converted to TDN by multiplying DOM by 1.06.

[3] TDN estimated from ADF in a commercial laboratory.

Upland pasture results

Crude protein and TDN values of diet samples, NUTBAL analyzed fecal samples, and hand-clipped forage from upland range are reported in Table 1. In September, diet samples contained more ($P \leq 0.01$) CP than NUTBAL samples, but in July and November, the CP content of both diet and NUTBAL samples were similar ($P > 0.90$). In all three months, TDN were inflated ($P < 0.05$) by the NUTBAL analysis. In July, the NUTBAL estimate of TDN was 9.2 percentage units greater than the fistulated cow samples, but in November the value was elevated by 18.1 percentage units. A TDN estimate off by 18 percentage units has dramatic impact on nutritional status of an animal and would result in erroneous supplementation recommendations.

Hand-clipped samples were lower in TDN than diet samples in all instances except for the July TDN estimate. However, clipped samples were closer to diet samples more often than were NUTBAL estimates. The clipped samples had a CP estimate that was 1 unit lesser than the diet samples in September, but were otherwise similar to the diet samples.

Subirrigated meadow results

Crude protein and TDN values of diet samples and NUTBAL analyzed fecal samples from meadows are reported in Table 2. In all July and November, the NUTBAL method underestimated ($P \leq 0.05$) the amount of CP in the diet. The NUTBAL method generally overestimated forage TDN. Forage TDN estimates were greater ($P < 0.01$) for NUBAL in September and November, but were not different in July ($P = 0.17$). No hand-clipped samples were taken on the wet meadows.

Overall NUTBAL slightly under estimated the amount of CP being consumed by grazing cattle and consistently overestimated the amount of TDN cattle were consuming on Nebraska Sandhills rangeland and meadows. Additionally, the NUTBAL estimates failed to capture the decline in forage quality as the grazing season progressed. The lack of consistency between NUTBAL and the diet samples precludes the possibility of developing an adjustment factor that can be applied to GAN lab reports in making useful cattle management decisions.

After NUTBAL analysis of this study's fecal samples were received by the GAN lab, the animal performance reports generated recommended feeding supplemental nutrients to prevent substantial body weight and body condition score loss. Supplemental nutrients were not fed and the animals did not lose the body weight and body condition score projected by the NUTBAL report (Table 3).

Conclusions

NUTBAL analysis of crude protein and energy numbers (from fecal sampling) differed from wet chemistry analysis of esophageally fistulated and hand-clipped forage samples. If cattle producers are solely utilizing NUTBAL for estimates of forage value, miscalculations for supplemental energy and protein requirements are likely,

Table 2. Crude protein (CP) and total digestible nutrient (TDN) content of diets collected from *subirrigated meadows* by esophageally fistulated cattle compared with NUTBAL analysis of fecal samples

Item	Diet[1]	NUTBAL[2]	SE	*P*-value
CP				
Jul	10.2	9.4	0.3	0.05
Sep	9.3	9.3	0.3	0.99
Nov	8.1	5.0	0.3	< 0.01
TDN				
Jul	58.9	60.6	1.2	0.17
Sep	51.2	60.3	1.2	< 0.01
Nov	43.9	55.8	1.2	<0.01

[1] TDN equal to digestible organic matter using in vitro organic matter digestibility.

[2] Digestible organic matter (DOM) was converted to TDN by multiplying DOM by 1.06.

Table 3. Actual body weight and body condition score of cows grazing upland range or meadow (no supplementation of adding nutrients).

Item	Jun	Jul	Sep	Nov
Upland range				
Body Weight, lbs.	954	909	968	1006
Body Condition Score	5.1	5.2	5.4	5.2
Meadow				
Body Weight, lbs.	1020	975	1022	1086
Body Condition Score	5.1	5.2	5.3	5.5

and may result in the purchase of unnecessary supplements, thereby reducing the profitability of the operation. Overall, crude protein was slightly underestimated and TDN was consistently overestimated in forage diets, and the decline in forage quality (summer to winter) was not captured through NUTBAL analysis.

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Biochar Supplementation in Growing and Finishing Diets

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Summary with Implications

Two metabolism studies were conducted to evaluate the effects of biochar (0, 0.8, or 3% of diet dry matter) on digestibility and methane production in growing and finishing diets. Intake was not affected by biochar inclusion in the growing diet and increased with 0.8% biochar inclusion in the finishing study. Digestibility tended to increase quadratically with biochar inclusion in the growing study while digestibility tended to linearly decrease with biochar inclusion in the finishing study. Methane production (g/d) decreased 10.7% in the growing study and 9.9% in the finishing study with 0.8% biochar compared to no biochar. Methane production was reduced 10.6% and 18.4% in the growing and finishing studies, respectively, when measured as g/lb of intake. Although biochar is not FDA approved for animal feeding, the initial research shows potential as a methane mitigation strategy in both growing and finishing diets.

Introduction

Energy lost as methane by ruminants can range from 2–12% of gross energy intake (GEI), but is variable depending on multiple things, with diet composition being one factor. Diet composition can be used to manipulate the rumen environment and is a methane mitigation strategy. Biochar is a feed product with potential as a methane inhibitor. Biochar is produced by burning organic matter (OM; typically plant material) at very high temperatures in the absence of oxygen. Although a mode of action is not fully understood, it has been suggested that it adsorbs gas in the rumen resulting in reduced methane eructation. Other theories are that the porous nature of biochar will increase the amount of inert surface area in the rumen, allowing for improved habitat for microbes to reside. This improved habitat may increase microbial growth, allow feeds to be digested more completely, and bring methanogens and methanotrophs together, leading to more complete oxidation of feeds and less methane production.

Table 1. Composition of diet (DM basis) fed to cattle (Growing trial)

	Biochar, % Inclusion		
Ingredient, % of diet DM	0	0.8	3
Brome hay	21	21	21
Wheat straw	20	20	20
Corn silage	30	30	30
Wet distillers grains plus solubles	22	22	22
Supplement[1]			
Fine ground corn	4.630	3.830	1.630
Biochar	-	0.800	3.000
Limestone	1.320	1.320	1.320
Tallow	0.175	0.175	0.175
Urea	0.500	0.500	0.500
Salt	0.300	0.300	0.300
Beef Trace Mineral[2]	0.050	0.050	0.050
Vitamin A-D-E[3]	0.015	0.015	0.015

[1] Supplement fed at 7% of diet DM

[2] Premix contained 10% Mg, 6% Zn, 2.5% Mn, 0.5% Cu, 0.3% I, and 0.05% Co

[3] Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E per g

[4] Formulated to supply Rumensin-90 (Elanco Animal Health; Greenfield, IN) at 18 g/ton

Procedure

Growing Experiment

Six crossbred steers (initial BW 1166 lb; standard deviation = 35 lb) were used in a 6-period crossover design. Steers were blocked by body weight (BW) and assigned randomly within block to 1 of 3 treatments. Periods ranged from 14–24 days with 2 consecutive, 23-h periods in the headbox calorimeter. The availability of the calorimeters dictated period length. Diets fed were identical between treatments other than inclusion of biochar (0, 0.8, or 3% of diet dry matter; DM), which displaced fine-ground corn in the supplement (Table 1). The biochar was derived from pine trees and had a composition of 85% carbon, 0.7% nitrogen, and was 94% OM on a DM basis. Diets consisted of 30% corn silage, 21% brome hay, 20% wheat straw, 22% wet distillers grains plus solubles (WDGS), and 7% supplement (DM basis). Urea was included in the supplement of all diets at 0.5% of diet DM and treatments provided 200 mg/animal daily of monensin (Rumensin, Elanco Animal Health, Greenfield, IN).

Diets were fed *ad libitum* twice daily with 50% of daily feed offered at each feeding. Each period consisted of adaptation to the treatments (minimum of 8 d), fecal grab sampling 4 times/d on 4 days leading up to headbox collections, and headbox collections for the final 2 d of the period. Feed and fecal samples were ground through a

Table 2. Composition of diet (DM basis) fed to cattle (Finishing trial)

	Biochar, % Inclusion		
Ingredient, % of diet DM	0	0.8	3
Dry-rolled Corn	53	53	53
Corn silage	15	15	15
Wet distillers grains plus solubles	25	25	25
Supplement[1]			
Fine ground corn	4.630	3.830	1.630
Biochar	-	0.800	3.000
Limestone	1.320	1.320	1.320
Tallow	0.175	0.175	0.175
Urea	0.500	0.500	0.500
Salt	0.300	0.300	0.300
Beef Trace Mineral[2]	0.050	0.050	0.050
Vitamin A-D-E[3]	0.015	0.015	0.015
Rumensin-90[4]	0.010	0.010	0.010

[1] Supplement fed at 7% of diet DM

[2] Premix contained 10% Mg, 6% Zn, 2.5% Mn, 0.5% Cu, 0.3% I, and 0.05% Co

[3] Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E per g

[4] Formulated to supply Rumensin-90 (Elanco Animal Health; Greenfield, IN) at 18 g/ton

Table 3. Effect of biochar inclusion on intake and total tract digestibility (Growing trial)

	0	0.8	3	SEM	Lin[1]	Quad[2]
DM						
Intake, lb/d	17.7	17.4	17.3	0.46	0.43	0.64
Digestibility, %	55.7	57.6	54.7	1.12	0.25	0.11
OM						
Intake, lb/d	16.0	15.8	15.7	0.42	0.52	0.74
Digestibility, %	58.6^{ab}	60.6^{a}	57.7^{b}	1.16	0.31	0.10
NDF						
Intake, lb/d	9.35	9.24	9.44	0.24	0.62	0.57
Digestibility, %	50.5^{ab}	52.6^{a}	48.2^{b}	1.55	0.08	0.10
ADF						
Intake, lb/d	6.24	6.22	6.46	0.18	0.13	0.53
Digestibility, %	46.7	48.1	45.0	1.50	0.29	0.35
Energy						
GE intake, Mcal/d	35.3	34.8	34.8	0.93	0.62	0.68
DE intake, Mcal/d	20.5	21.0	20.0	0.51	0.27	0.30

[1] Linear effect on response variables

[2] Quadratic effect on response variables

$^{a, b}$ Means within a row with different superscripts are different ($P < 0.10$)

1-mm screen and analyzed for DM, OM, acid detergent fiber (ADF), neutral detergent fiber (NDF), GE and digestible energy (DE). Bomb calorimetry was done to obtain energy values. Acid insoluble ash (AIA) was used as an internal marker and analysis was done on the base diet fed, feed refusals, and fecals to determine digestibility DMD.

Finishing Experiment

The same 6 steers were utilized in a 3-period crossover design. Steers remained in the same BW block and were assigned randomly to 1 of 3 treatments. Similar to the growing experiment, diets fed were identical between treatments other than inclusion of biochar (0, 0.8, or 3% of diet DM), which displaced fine-ground corn in the supplement (Table 2). Diets consisted of 53% dry rolled corn, 15% corn silage, 25% WDGS, and 7% supplement, on a DM basis. Periods were 14 days in length with 2 consecutive 23-hr headbox collections over the last 2 days of each period. Fecal output was estimated by dosing 10 g/d of titanium dioxide in the feed and was used to calculate diet digestibility. All other procedures were the same as described for the growing experiment. At the conclusion of the trial, cattle were euthanized under veterinary supervision and composted because biochar is not an FDA approved feed additive.

Gas emissions

In both experiments, methane emissions were measured through indirect calorimetry using headboxes built at the University of Nebraska–Lincoln. A training period was done before the experiment for steers to become acclimated to the headboxes. One steer was removed from the growing experiment after period two because of a lack of dry matter intake (DMI) while in the headbox, but was re-trained and used during the finishing experiment. Gas samples were collected in foil bags that continuously and evenly filled throughout the 23 h collection period. Gas measurements collected over the 2 d were averaged to obtain 1 value per period for each steer. A 5 d DMI average leading up to the 2 d headbox period was used to report gas emissions on a grams per lb of DMI basis.

Digestibility and gas emissions were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Steer within period was the experimental unit and steer was included in the random statement. Probabilities were considered significant at $P \leq 0.10$ and tendencies are discussed at $P \leq 0.15$.

Results

Growing Experiment

DIGESTIBILITY AND ENERGY

All intake, fecal output and digestibility data are reported in Table 3. Dry matter intake (lb/d) did not differ between treatments ($P \geq 0.43$; Table 3), but did increase between periods as a result of the cattle growing, and therefore eating more. There were no differences between treatments in intake of DM, OM, NDF, or ADF ($P \geq 0.13$). Dry matter digestibility and OM digestibility (OMD) were not different ($P \geq 0.15$) from the control diet at either biochar inclusion. A linear ($P = 0.08$) decrease was observed for NDF digestibility (NDFD) with 3% inclusion of biochar having the lowest digestibility. Gross energy intake (GEI; Mcal/d) and digestible energy intake (DEI; Mcal/d) did not differ between treatments ($P \geq 0.27$).

METHANE PRODUCTION

Reported DMI used for gas emission calculations was a 5 d average prior to cattle entering the headboxes, and was not different between treatments ($P \geq 0.68$; Table 4). Methane production (g/d) tended to decrease quadratically ($P = 0.14$) with the 0.8% biochar treatment reducing methane compared to the 0% treatment. Numerically, the 0.8% biochar treatment reduced methane (g/d) by 11% compared to the control treatment without biochar. Methane production calculated as g/lb of DMI or g/Mcal of GEI was not different between treatments ($P \geq 0.17$). Methane produced per Mcal of DEI was lowest for 0.8% biochar and greatest for the 0% treatment, resulting in a quadratic response ($P = 0.05$).

When combining the two treatments that contained biochar (0.8 and 3%) and comparing to the 0% biochar treatment, methane production (g/d, g/lb DMI, and g/Mcal GEI) tended ($P \leq 0.13$) to be lower for the biochar cattle relative to the control cattle. Methane produced per Mcal of DEI was reduced ($P = 0.07$) for the biochar cattle.

Finishing Experiment

DIGESTIBILITY

Intake of DM, OM, NDF, and ADF all increased quadratically ($P < 0.01$) as biochar inclusion in the diet increased (Table 5). Dry matter digestibility tended to decrease linearly ($P = 0.11$) as biochar inclusion increased, while OMD and ADFD did decrease linearly ($P \leq 0.10$) as biochar inclusion increased.

Table 4. Effect of increasing inclusion of biochar on methane emissions from steers (Growing trial)

	Biochar Inclusion, % DM				*3 Types P-value*		*Bio vs No Bio*[3]
	0	0.8	3	SEM	Lin[1]	Quad[2]	*P*-value
DMI, lb/d	17.4	17.4	17.2	0.4	0.68	0.90	0.70
GE intake, Mcal/d	34.9	34.7	34.8	0.9	0.99	0.85	0.88
DE intake, Mcal/d	20.6	21.1	20.3	0.5	0.50	0.32	0.82
Methane							
g/d	108.8	97.2	100.7	5.1	0.42	0.14	0.11
g/lb DMI	6.25	5.59	5.85	0.30	0.43	0.18	0.13
g/Mcal GE intake	3.10	2.80	2.86	0.13	0.37	0.17	0.11
g/Mcal DE intake	5.27[a]	4.62[b]	4.92[ab]	0.21	0.51	0.05	0.07

[1] Linear effect on response variables

[2] Quadratic effect on response variables

[3] Biochar vs. No biochar inclusion

[a, b] Means within a row with different superscripts are different ($P < 0.10$)

Table 5. Effect of biochar inclusion on intake and total tract digestibility (Finishing trial)

	0	0.8	3	SEM	Lin[1]	Quad[2]
DM						
Intake, lb/d	26.4[a]	28.5[b]	26.8[a]	1.2	0.48	< 0.01
Digestibility, %	71.5	70.0	68.2	1.8	0.12	0.70
OM						
Intake, lb/d	22.5[a]	24.4[b]	22.8[a]	1.0	0.33	< 0.01
Digestibility, %	72.3[a]	70.4[ab]	68.7[b]	1.7	0.10	0.45
NDF						
Intake, lb/d	6.62[a]	7.40[b]	7.47[b]	0.33	< 0.01	< 0.01
Digestibility, %	56.6	54.1	53.4	3.8	0.22	0.43
ADF						
Intake, lb/d	2.82[a]	3.18[b]	3.38[c]	0.13	< 0.01	< 0.01
Digestibility, %	52.4[a]	50.1[a]	41.3[b]	3.8	< 0.01	0.75

[1] Linear effect on response variables

[2] Quadratic effect on response variables

[a,b,c] Means within a row with different superscripts are different ($P < 0.10$)

Table 6. Effect of increasing inclusion of biochar on methane emissions from steers (Finishing trial)

	Biochar Inclusion, % DM				*3 Types P-value*		*Bio vs No Bio*[3]
	0	0.8	3	SEM	Lin[1]	Quad[2]	*P*-value
DMI, lb/d	24.8[a]	28.0[b]	26.3[b]	1.1	0.52	0.01	0.04
Methane							
g/d	141	127	122	19	0.39	0.62	0.32
g/lb DMI	5.65	4.61	4.83	0.66	0.48	0.85	0.22

[1] Linear effect on response variables

[2] Quadratic effect on response variables

[3] Biochar vs. No biochar inclusion

[a, b] Means within a row with different superscripts are different ($P < 0.10$)

METHANE PRODUCTION

Intake used for gas emission calculations increased quadratically ($P = 0.01$) as biochar inclusion increased. When biochar treatments were combined, biochar cattle had greater DMI ($P = 0.04$) than the control. Methane production (g/d and g/lb DMI) was not different between treatments ($P \geq 0.22$) when analyzed as three inclusion levels or as biochar inclusion vs. no biochar inclusion (Table 6). However, methane production (g/d) numerically decreased 9.9% and methane production (g/lb DMI) decreased 18.4% for the 0.8% biochar treatment relative to no biochar. Only 3 periods of data were collected in the finishing experiment (6 periods in the growing experiment) due to cattle becoming too large for the headboxes, which limited statistical power.

While not always statistically significant, there were consistent numerical decreases in methane production with 0.8% biochar inclusion in the diet compared to no biochar. Intake was not hindered with biochar inclusion, and actually increased in the finishing experiment. Feeding 0.8% biochar appears to be sufficient and no further benefits were observed from increasing inclusion to 3% of diet DM. The effects of biochar in the rumen show promise, but are not fully understood and performance data (ADG, efficiency, carcass data) are needed to determine if it is a feasible methane mitigation tool.

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Corn Oil Supplementation on Performance and Methane Production in Finishing Steers

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Summary with Implications

A finishing trial was conducted to evaluate the effects of corn oil on animal performance, carcass characteristics, and methane production in finishing cattle. Corn oil was supplemented at 3% of the diet (dry matterbasis) and led to a decrease in intake, a numerical improvement in average daily gain, and improved feed efficiency compared to the control cattle. Dry matter intake while in the methane barn was not decreased between treatments, although it was numerically similar to what was observed outside of the methane barn. Corn oil did not affect any carcass parameters. Methane production (g/d) was reduced with the inclusion of corn oil compared to the control. Methane (g/lb of gain) was also reduced with the inclusion of corn oil compared to the control. A numerical reduction of methane (g/lb of intake) was observed when corn oil was included in the diet. Corn oil appears to be a viable option for both improving performance as well as decreasing methane production in beef cattle finishing diets.

Introduction

Methane production from ruminant animals has been a focus in research studies due to the environmental concerns associated with rising levels of greenhouse gases. Ruminants, especially beef cattle, have received attention due to the amount of methane they contribute to the global methane budget. Ruminants contribute 17% of the global methane production, but when fed grain, like in the US, cattle produce less per unit of energy intake. The environmental concerns are a main reason that mitigation strategies are being pursued in cattle production, but the energetic loss to the animal associated with methane production is another concern. A strategy for methane mitigation is through lipid supplementation. There are three ways that dietary lipids reduce methane: 1) biohydrogenation of fatty acids, 2) increased propionate production from lipolysis converting triglycerides to glycerol, which is then converted to propionate by anaerovibrio lipolytica bacteria, and 3) reduction in available fermentable substrate in the rumen as fatty acids are not fermentable. Fats are an energetic feed and can improve performance as well as mitigate methane, but should not be included in excess of 6–7% of dietary dry matter (DM) as rumen fermentation can be reduced at higher inclusion levels. The objective of this study was to evaluate the effect of corn oil supplemented at 3% of diet DM on performance and methane production.

Table 1. Treatments fed to control and corn oil cattle on finishing diets (DM basis)

Ingredient, % of diet DM	Control	Corn Oil
Dry-rolled corn	33	31.5
High-moisture corn	33	31.5
Wet distillers grains plus solubles	15	15
Corn silage	15	15
Corn oil	-	3
Supplement[1]		
Fine ground corn	1.368	1.368
Limestone	1.640	1.640
Tallow	0.100	0.100
Urea	0.500	0.500
Salt	0.300	0.300
Beef Trace Mineral[2]	0.050	0.050
Vitamin A-D-E[3]	0.015	0.015
Rumensin[4]	0.017	0.017
Tylan[5]	0.011	0.011

[1] Supplement fed at 4% diet DM

[2] Premix contained 10% Mg, 6% Zn, 2.5% Mn, 0.5% Cu, 0.3% I, and 0.05% Co

[3] Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E per g

[4] Formulated to supply Rumensin-90 (Elanco Animal Health, Greenfield, IN) at 30 g/ton

[5] Formulated to supply Tylan-40 (Elanco Animal Health) at 8.8 g/ton

Procedure

A 127-day finishing study was conducted using 80 steers (initial BW = 814 lb; SD = 55). Cattle were limit-fed a common diet of 50% alfalfa and 50% Sweet Bran (Cargill Corn Milling, Blair, NE) at 2% of body weight (BW) for 5 d (to equalize gut fill) and weighed on two consecutive days in order to obtain an accurate average initial BW. Steers were blocked by BW within previous treatment (ad-libitum or limit-fed forage diets; *2018 Nebraska Beef Cattle Report*, pp. 55–56), stratified within BW block, and assigned randomly to pens. Pens were assigned randomly to one of two treatments (Control and Corn Oil; Table 1), with 10 steers/pen and 4 pens/treatment.

The corn oil was sourced from an ethanol plant and displaced 3% of a dry-rolled corn (DRC):high-moisture corn (HMC) blend with corn oil (DM basis). Cattle were adapted to the finishing diet over a 24 d step-up period. Adaptation diet included

15% wet distillers grains plus solubles, 4% supplement, and displaced 81% corn silage down to 15% with DRC:HMC blend. Corn oil was introduced on day 18. The supplement was formulated to provide 30 g/ton of Rumensin (Elanco Animal Health) and 8.8 g/ton of Tylan (Elanco Animal Health). On d 1, cattle were implanted with 100 mg trenbolone acetate and 14 mg estradiol benzoate (Synovex Choice, Zoetis Animal Health). The steers were harvested on d 128 at Greater Omaha (Omaha, NE). Hot carcass weight and liver abscesses were recorded during harvest, and a dressing percentage of 63% was used to calculate final BW. Following a 48-hr chill, fat thickness, LM area, and USDA marbling scores were recorded and yield grade was calculated.

Table 2. Effects of corn oil supplementation (3% of diet DM) in finishing diets on cattle performance and carcass characteristics

	Control	Corn Oil	SEM	*P*-value
Performance				
Initial BW, lb	815	813	2	0.54
Final BW, lb	1302	1314	8	0.38
DMI, lb / d^1	25.7	24.6	0.2	0.03
ADG, lb /d	3.84	3.96	0.04	0.15
F:G	6.69	6.22	-	0.02
Carcass Characteristics				
HCW, lb	821	828	5	0.39
LM area, in^2	12.7	13.1	0.18	0.26
Fat thickness, in	0.57	0.55	0.03	0.63
Marbling score^2	497	484	9	0.43
Calculated YG^3	2.98	2.85	0.09	0.35

^{1}DMI over the 127 d trial

^{2}Marbling score: 400 = Small^{00}, 450 = Small^{50}, 500 = Modest^{00}, etc.

^{3}YG = 2.50 + (0.9843 * rib fat thickness, cm) + (0.2 * 2.5% KPH), + (0.0084 * HCW)–(0.0496 * LM area, cm^2) (USDA, 2016)

Steers were rotated through two pen-scale methane chambers with two side-by-side enclosed dry-lot pens sharing a middle wall. Gravity inlets on the south wall of the building allowed air to enter the chambers. Air is drawn through the inlets using two fans on the north wall, creating a negative pressure system. Air is pulled through each chamber and exits through the fans, with a sampling line positioned above the fans. Fans were calibrated twice, once prior and once after the trials (FANS System, Iowa State University). Airflow through the chambers with two fans running was 2800 cubic feet/minute. Air in each chamber was pulled into a sampling line with a pump. Solenoids controlled by a data logger cycled airflow from outdoors (ambient air), chamber 1, and chamber 2 to the gas analyzers, allowing air from each chamber to be analyzed for 6 minutes of each 20-minute cycle, with 2-minute or 6-minute ambient air flushes occurring between chambers.

Gas concentration data were averaged across each 6-minute measurement period, excluding readings for the first 30 seconds after solenoid switching to ensure that gases from the previous source were evacuated from the system. Daily gas production was calculated as an average of all of the 6-minute concentrations, minus the average ambient concentrations, multiplied by the [constant] daily airflow through each chamber. Each week, measurements were taken with cattle in the methane barn for five consecutive days, then with the cattle removed and manure remaining for 1 d, followed by manure being removed and clean chambers for 1 d. With eight total pens of cattle and two chambers in the methane barn each pen of cattle was in the barn for one 5 d period every 4 weeks. Each treatment was represented during every weekly sampling period in the methane barn, as each block replication had emission collections at the same time. Each pen of cattle had three 5 d collection periods throughout this trial, and pens were alternated between chamber 1 and chamber 2 each rotation through the methane barn.

Data were analyzed using the MIXED procedure in SAS as a randomized complete block design with all blocks (n=4) having one replication. Pen was the experimental unit and BW block was treated as a fixed effect. Gas production data were gathered over three periods, so the data were analyzed using repeated measures. Treatment, period, and block were included in the model as fixed effects. Treatment-by-period interactions were tested for methane production across time, but were not significant, therefore, main effects will be shown.

Results

Performance

Performance data are shown in Table 2. Initial BW and final BW were not different ($P \geq 0.39$), while dry matter intake (DMI) was reduced ($P = 0.02$) for cattle fed 3% corn oil compared to the control. Corn oil did not show a significant effect ($P = 0.14$) on average daily gain (ADG), although a numerical improvement of 3% was observed for the corn oil treatment. Feed conversion (F:G) was improved ($P = 0.02$) by 7% for the corn oil cattle over the control cattle, which is what is expected as ADG was not different but DMI was lower for the corn oil cattle. All carcass characteristics were similar between treatments in this trial ($P \geq 0.27$).

Methane

Methane data are shown in Table 3. Methane production (g/d) was reduced ($P = 0.03$) by 13% with the inclusion of corn oil relative to the control diet. Methane production (g/d) was greater as time on feed (period) progressed, regardless of treatment, shown by the period effect ($P < 0.01$). Methane (g/lb DMI while in the chamber) was numerically reduced by 13% when corn oil was included compared to the control. This study showed a 15% reduction ($P < 0.01$) in methane as g/lb ADG when corn oil was included compared to the control. Methane production from manure without cattle in the pens was small (0.9 g/steer daily). Methane from manure may be underestimated using these methods because of continuous methane release from the manure over the 5 d period, resulting in less volatiles being released on d 6 (during the measurement period) than when first excreted from the animal. Cattle were not present while manure emissions were

Table 3. Effects of corn oil supplementation (3% of diet DM) on methane production from cattle fed finishing diets

				P-value	
	Control	Corn Oil	SEM	TRT	Period
DMI, lb[2]	23.7	23.1	0.5	0.72	0.80
Methane					
g / d	132	115	3	0.03	< 0.01
g / lb DMI[1]	5.13	4.68	0.09	0.04	-
g / lb DMI[2]	5.82	5.05	0.43	0.29	0.50
g / ADG[3]	34.3	29.1	0.4	< 0.01	-

[1] DMI over the 127 d trial

[2] DMI in the methane barn across all 3 periods of collection

[3] ADG, lb over the 127 d trial

being measured. During the day of manure measurements alone, the manure is not being mixed by cattle activity, which could also reduce emissions. All data reported in tables 2 and 3 have ambient air concentrations of methane removed from the concentrations measured in each chamber to get more accurate production of gases. All of the gas production results shown in tables 2 and 3 are pen totals divided by ten to express values on a per-steer basis.

Conclusion

Supplementing 3% corn oil (DM basis) to finishing cattle reduced DMI, but resulted in numerically greater ADG as well as improved feed conversions. Supplementing corn oil reduced the amount of methane produced per day and per unit of gain (g/d, g/lb ADG) and numerically reduced methane per unit of intake (g/lb DMI) compared to the control. Overall, supplementing corn oil to finishing cattle seems to be a viable way to decrease methane production while improving cattle performance if supplemented at 3% of diet DM with 15% distillers grains. Price and logistics of feeding corn oil would need to be considered by producers prior to adding back dietary corn oil.

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Impact of Corn Silage Inclusion on Finishing Cattle Performance

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Summary with Implications

Cattle fed high grain diets with little to no roughage are typically at greater risk for acidosis and reduced dry matter intake and average daily gain. An individual feeding study was conducted to compare different inclusions of corn silage used as a roughage source on finishing performance and liver abscess rate. Treatments consisted of 3 inclusions of corn silage at 0, 7.5 and 15% of the diet DM and a control treatment with 7.5% alfalfa. There were no differences for live animal performance or carcass characteristics. There were also no differences in liver abscess incidence. Feeding corn silage at 15% gave similar performance responses compared to 7.5% alfalfa. These data suggest that roughage is not required in a finishing diet when feeding individual animals.

Introduction

Cattle fed all-concentrate diets may suffer from rumenitis, acidosis, and liver abscesses when fed for an extended period of time. Including roughage in a feedlot ration promotes rumen health and buffers rumen pH to mitigate risk of acidosis and digestive upset from highly fermentable carbohydrates. In the US, most cattle feeders include roughage in finishing diets at an inclusion of 0 to 13% (Dry matter basis; DM basis) averaging 8.3 to 9%, depending on season, with the most common roughage sources as alfalfa or corn silage. However, traditional inclusion of roughages can be subjective based on corn processing, inclusion of byproducts, and forage type.

Table 1. Composition (% of diet DM) of dietary treatments fed to calf-fed steers.

	Treatment[1]			
Ingredient	Alf	CS0	CS7.5	CS15
Dry-rolled corn	33.75	37.5	33.75	30
High-moisture corn	33.75	37.5	33.75	30
Alfalfa	7.5	-	-	-
Corn Silage	-	-	7.5	15
WDGS[2]	20	20	20	20
Supplement[3]				
Fine Ground Corn	2.27	2.27	2.27	2.27
Limestone	1.71	1.71	1.71	1.71
Tallow	0.125	0.125	0.125	0.125
Urea	0.5	0.5	0.5	0.5
Salt	0.3	0.3	0.3	0.3
Vitamin A-D-E Premix	0.05	0.05	0.05	0.05
Beef Trace Minerals Premix	0.015	0.015	0.015	0.015
Rumensin[4] Premix (g/ton)	0.17	0.17	0.17	0.17
Tylosin[5] Premix (mg/d)	0.009	0.009	0.009	0.009
Analyzed Nutrient Composition, % of DM				
Organic Matter	93.3	93.5	92.6	91.8
Neutral Detergent Fiber	23.8	19.8	22.3	24.7
Acid Detergent Fiber	10.8	7.15	9.30	11.5
Crude Protein	12.3	11.8	11.8	11.8

[1] Treatments included Alf: Alfalfa included at 7.5% of diet DM; CS0: contained no corn silage or alfalfa; CS7.5: corn silage included at 7.5% of diet DM; CS15: corn silage included at 15% of diet DM.

[2] WDGS: wet distillers grains.

[3] Supplement fed at 5% of dietary DM for all treatments.

[4] Formulated to supply Rumensin-90 (Elanco Animal Health) at 30 g per ton DM.

[5] Formulated to supply Tylan-40 (Elanco Animal Health) at 90 mg per steer daily.

Corn silage, on a DM basis, is approximately 50% concentrate (corn grain) and 50% roughage from leaves, stalk, and husk. Currently, it is common for producers to include corn silage at 7.5% of the diet DM as a roughage source. However, because of grain content, it may be beneficial to include corn silage at greater inclusions. It is logical that if silage is included at 15% of the diet DM, 7.5% of that would be corn grain and 7.5 % would be roughage. The objective of this study was to determine the effects of feeding no roughage, 7.5% or 15% corn silage, compared to traditional alfalfa hay at common inclusions of 7.5% DM basis.

Procedure

A finishing experiment conducted at the Eastern Nebraska Research and Extension Center utilized 60 individually fed crossbred steers (initial shrunk body weight 952 lbs ± 47 lbs). Steers were limit-fed a diet of 50% alfalfa and 50% Sweet Bran at 2% of body weight (BW) for 5 days prior to start of trial to reduce variation in gut fill, then 3 consecutive day weights were collected, utilizing the average as initial BW. Steers were stratified by body weight and assigned randomly to one of four treatments. Treatments consisted of 3 inclusions of corn

Table 2. Live performance and carcass characteristics of finished steers fed corn silage at two levels as a roughage source compared to no roughage or an alfalfa control.

	Treatment[1]					*P*–value[2]		
Item	Alf	CS0	CS7.5	CS15	SEM	*Alf v CS15*	Linear	Quadratic
Carcass Adjusted Performance								
Initial BW, lb	953	953	953	951	12.8	0.93	0.92	0.95
Live final BW, lb[3]	1375	1389	1388	1383	18.5	0.75	0.82	0.92
Final BW, lb[4]	1380	1393	1382	1368	18.9	0.67	0.36	0.94
DMI, lb/d	25.8	24.6	25.3	25.2	0.57	0.50	0.42	0.54
ADG, lb	3.65	3.76	3.67	3.57	0.12	0.63	0.27	0.97
F:G	7.10	6.60	7.04	7.22	-	0.75	0.08	0.67
Carcass Characteristics								
HCW, lb	842	)850	843	835	11.5	0.67	0.36	0.94
Marbling[5]	430	426	440	408	16.7	0.36	0.43	0.27
LM area, in^2	12.9	13.3	13.2	13.2	0.38	0.53	0.84	0.95
12th rib fat, in	0.47	0.50	0.44	0.43	0.03	0.42	0.14	0.56
Dressing, %	61.3	61.1	60.5	60.3	0.39	0.10	0.16	0.60
Liver Abscesses, %[6]	7.1	13.3	0	0	0.08	0.96	0.98	0.99
Calculated Yield Grade[7]	3.25	3.20	3.02	3.03	0.15	0.32	0.43	0.61

[1]Treatments included Alf: Alfalfa included at 7.5% of diet DM; CS0: contained no corn silage or alfalfa; CS7.5: corn silage included at 7.5% of diet DM; CS15: corn silage included at 15% of diet DM.

[2]Alf v CS15: Orthogonal contrast comparing 7.5% alfaf and 15% corn silage. Orthogonal contrasts for linear and quadratic effects of silage inclusion.

[3]Live final BW is the average individual 2 day weight shrunk 4.0%, Subsequent ADG and G:F are calculated from 4.0% shrunk EBW.

[4]Final BW calculated based on HCW using a common dressing percent of 61.0%.

[5]Marbling Score 300 = Slight, 400 = Small, 500 = Modest, etc.

[6]Calculated as a percent of total animals

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

silage at 0 (CS0), 7.5 (CS7.5) or 15% (CS15) of the diet DM and a control treatment with 7.5% alfalfa (Alf; Table 1). Cattle fed Alf and CS15 were stepped up over 21 days in 5 steps. Cattle fed CS0 and CS7.5 were stepped up for 28 days over 6 steps. Cattle were fed individually, *ad libitum*, using a Calan Gate system. All steers were fed for 117 days and harvested at Greater Omaha to collect carcass data (hot carcass weight, HCW; marbling, longissimus muscle area, LM area; fat thickness, liver abscesses).

Carcass and performance data were analyzed using the MIXED procedure of SAS where animal was the experimental unit and treatment was a fixed effect. Orthogonal contrasts were used to test linear and quadratic effects of corn silage inclusion. Liver abscess incidence was analyzed using PROC GLIMMIX of SAS as binomial data with treatment as a fixed effect.

Results

When evaluating the effects of different silage levels against an alfalfa control there was no significant difference for ending BW, dry matter intake (DMI), average daily gain (ADG) or feed to gain (F:G) ($P \geq 0.75$; Table 2). Animals did not perform as expected. As observed in the digestion study (*2019 Nebraska Beef Cattle Report*, pp. 66–68) intake decreased with lesser roughage inclusion. Changes in DMI led to differences in ruminal pH and VFA concentration. If animals in this study had differences in DMI, it may have altered severity of acidosis and affected animal performance. There was no significant difference for HCW, marbling, LM area, 12th rib fat, liver abscesses or calculated yield grade ($P \geq 0.45$). Dressing percent was not statistically significant for all treatments ($P = 0.12$). However, there was a linear response ($P = 0.02$) for corn silage inclusion where dressing percentage was greatest for CS0 and linearly declined with increasing inclusions of silage. The distributions of calculated yield grade and quality grade were not different for treatment ($P \geq 0.30$). There were numerically greater ($P = 0.96$) number of liver abscesses for cattle fed no roughage (13%) compared to Alf (7%) or CS7.5 and CS15 (0%).

Conclusion

These results suggest that corn silage can be ed up to 15% of diet DM without adversely affecting animal performance or carcass characteristics. Steers did not have reduced DM intakes as expected when fed lower inclusions of roughage. This could change the severity of acidosis experienced by cattle fed lesser roughage resulting in reduced effects on performance. It is important to note that animals were individually fed, and results may have been affected if animals were fed in a pen. When priced favorably, corn silage can be an economical roughage source in a feedlot and can be utilized without detrimentally affecting performance or carcass merit. However, this study shows no roughage is needed in a finishing diet when individually fed.

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Impact of Corn Silage Inclusion on Nutrient Digestion and Rumen Fermentation in Finishing Cattle

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Summary with Implications

A digestion study was conducted comparing different inclusions of corn silage used as a roughage source on digestibility, feeding behavior and rumen environment. Treatments consisted of 3 inclusions of corn silage at 0, 7.5 and 15% of the diet DM, and a control treatment with 7.5% alfalfa. As expected, increasing available energy and decreasing roughage (either silage or alfalfa) showed an increase in diet digestibility and ruminal propionate concentrations. However, average ruminal pH was least, with more time spent in subacute acidosis (pH < 5.3) when cattle were fed no roughage. These data suggest that feeding cattle increasing silage inclusions as a roughage source prevented ruminal conditions from entering and remaining in subacute acidosis. Feeding corn silage at 15% gave similar digestibility responses compared to 7.5% alfalfa. Including silage as a roughage source at 15% could help prevent acidosis and digestive upset in feedlot cattle.

Introduction

Feeding a high grain diet increases the risk for acidosis and liver abscesses in feedlot cattle. Roughages are included in feedlot rations to help minimize the risk for digestive upset caused by highly fermentable carbohydrate by buffering rumen pH. Corn silage is fed as a roughage source in many feedlots. However, it is necessary to consider the grain portion of corn silage when deciding inclusion levels in a feedlot diet. Because corn silage is approximately 50% corn grain and 50% roughage, greater inclusions may be required to achieve the same buffering capacity as a traditional forage. The objective of this study was to determine the effects of feeding no roughage, 7.5% or 15% corn silage, compared to feeding alfalfa hay at 7.5% of diet DM, on ruminal pH, VFA concentrations, and digestibility.

Procedure

A digestion study was conducted using 4 ruminally cannulated steers (948 lbs ± 0.04 lbs) in a row-column design. Steers were assigned randomly to the same 4 treatments as described in the performance study (*2019 Nebraska Beef Cattle Report*, pp. 63–65); 3 inclusions of corn silage at 0 (CS0), 7.5 (CS7.5) or 15% (CS15) of the diet DM and a control treatment with 7.5% alfalfa (Alf). The study consisted of 8 periods, 21 days long with 17 days of adaptation and 4 days of collection. One steer was removed from study due to the steer removing the rumen canula during multiple periods.

Steers were fed once daily at 0800 h. Feed refusals were removed daily prior to feeding. Refusals were collected on d 17 to 21. Each pen was fitted with a feed bunk that was suspended from a load cell to determine the eating behavior of each animal and weight measurements were recorded every 5 seconds. These measurements were averaged by minute and analyzed for number of meals, length of meal, and average amount eaten at each meal. A meal was considered the change in weight, greater than or equal to 0.15 lbs, before or after a 10-minute period of inactivity (rest period).

Steers were dosed 2 times, daily, on days 10–20, intraruminally, with titanium dioxide (10 g/d) to determine fecal output. Fecal grab samples were taken at 0800, 1200, 1600, and 2000 h and composited wet on days 17–20. The lyophilized and ground daily composites were then composited on a dry weight basis by steer within collection period. Fecal samples were analyzed for titanium dioxide concentration and used to determine total tract digestibility. Feed and fecal samples were also analyzed for gross energy content (calories/g) using a bomb calorimeter. Digestible energy was calculated by subtracting the fecal energy from the total gross energy intake. Wireless pH loggers were submerged into the rumen on day 14. Ruminal pH was measured every 5 seconds and averaged per minute on days 17–21. Dry bran (0.5 g) was placed in 5 × 10 cm in situ bags. In situ bags (6) were submerged into the rumen for 24 h on day 20. NDF disappearance was determined using the Ankom Fiber Analyzer. Samples of individual ingredients were taken prior to mixing diets, composited by period, lyophilized and ground through a 1-mm screen using a Wiley mill. Feed and fecal samples were analyzed for nutrient composition.

Rumen fluid was analyzed for VFA concentration following collections on day 20 at 0800, 1000, 1200, and 1400 h using a vacuum hand pump. Once samples thawed, they were analyzed for VFA concentration using gas chromatography.

Digestibility, in situ DM disappearance, gas production and gas production rate data were analyzed with 3 steers using the MIXED procedure of SAS with treatment and period as fixed effects and steer as random. Orthogonal contrasts were used to determine linear and quadratic relationships between CS0, CS7.5 and CS15. PROC MIXED was also used for VFA data where period, treatment, hour and the interaction between hour and treatment were included in the model with steer as random. Intake parameters were analyzed using PROC GLIMMIX with treatment as fixed effects and steer and period as random. The pH data were averaged over day and analyzed using the MIXED procedure of SAS with treatment, day and day by treatment interaction included in the model and day being considered a repeated measure with period as random. The pH data were also averaged over hour to analyze daily variation. Hourly pH data were analyzed the same as day but using hour as the repeated measure. Treatment differences were declared significant for all statistical analysis at $P \leq 0.10$.

Table 1. Diet intake and digestibility for steers fed corn silage at two levels as a roughage source compared to no roughage or an alfalfa control

	Treatment[1]					P–value[3]		
Item[2]	Alf	CS0	CS7.5	CS15	SEM	F-test	Linear	Quadratic
DM								
intake, lb	26.4	25.5	28.4	26.8	0.97	0.18	0.27	0.07
digestibility, %	74.2^{b}	82.0^{a}	76.6^{b}	73.0^{b}	1.26	< 0.01	<0.01	0.40
OM								
intake, lb	24.4	23.8	26.4	24.6	0.90	0.23	0.50	0.06
digestibility, %	75.2^{bc}	82.8^{a}	77.7^{b}	73.5^{c}	1.34	<0.01	<0.01	0.72
NDF								
intake, lb	6.25^{a}	5.06^{b}	6.34^{a}	6.69^{a}	0.22	<0.01	<0.01	0.11
digestibility, %	61.3^{b}	72.5^{a}	62.0^{b}	56.9^{b}	2.42	<0.01	<0.01	0.38
ADF								
intake, lb	2.86^{ab}	1.84^{c}	2.64^{b}	3.10^{a}	0.09	<0.01	<0.01	0.18
digestibility, %	55.5^{b}	73.5^{a}	58.0^{b}	54.4^{b}	2.46	<0.01	<0.01	0.03
DE, Mcal/lb	7.57^{b}	8.40^{a}	7.77^{b}	7.52^{b}	0.11	<0.01	<0.01	0.15
DE, Mcal/d	41.3	44.0	45.8	41.7	1.44	0.15	0.28	0.13
Bran in situ NDF digestibility, %[4]	20.9	20.1	21.1	20.3	1.34	0.94	0.90	0.60

$^{a-c}$Means in a row with different superscripts are different (P < 0.10)

[1] Treatments included Alf: Alfalfa included at 7.5% of diet DM; CS0: contained no corn silage or alfalfa; CS7.5: corn silage included at 7.5% of diet DM; CS15: corn silage included at 15% of diet DM.

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

[3] F-test comparing all 4 treatments, linear and quadratic effects of silage inclusion

[4] Incubated for 24 hours inside steers fed treatment diets

Table 2. Eating behavior of steers fed corn silage at two levels as a roughage source compared to no roughage or an alfalfa control

	Treatment[1]					P–value[2]		
Item	Alf	CS0	CS7.5	CS15	SEM	F-test	Linear	Quadratic
Meals, n	14.3	13.7	13.9	15.3	1.1	0.60	0.20	0.60
Time per meal, min	15.1^{a}	15.3^{a}	13.7^{ab}	12.5^{b}	1.3	0.10	0.10	0.90
Meal size, lb DM	1.96	1.90	2.14	1.99	0.08	0.80	0.72	0.38
Meal size/ total DMI, %	7.64	7.79	7.67	7.17	0.06	0.75	0.33	0.73
rate, lb DM/hr	8.12^{bc}	7.68^{c}	9.44^{ab}	9.55^{a}	0.31	0.09	0.04	0.22

$^{a-c}$Means in a row with different superscripts are different (P < 0.10)

[1] Treatments included Alf: Alfalfa included at 7.5% of diet DM; CS0: contained no corn silage or alfalfa; CS7.5: corn silage included at 7.5% of diet DM; CS15: corn silage included at 15% of diet DM.

[2] F-test comparing all 4 treatments, linear and quadratic effects of silage inclusion

Results

There was a quadratic effect for DM intake from silage inclusion (P = 0.07; Table 1). These results were expected but differed from the performance study where no differences in intake or performance were observed (*2019 Nebraska Beef Cattle Report*, pp. 63–65). Steers fed Alf had similar intakes to all silage treatments (P = 0.18). Dry matter digestibility decreased linearly from CS0 to CS15 (P < 0.01). Steers fed Alf had similar DMD to both CS7.5 and CS15. Organic matter intake was not different for Alf and all silage treatments (P = 0.23) but showed a significant quadratic response to increasing inclusion of silage with CS7.5 having the greatest OMI (P = 0.06). There was a significant difference among all treatments (P < 0.01) for OMD where Alf was similar to both CS7.5 and CS15 but all lesser than CS0. There was a linear decrease in OMD with increasing silage inclusion (P < 0.01). There was a significant difference (P < 0.01) for NDF and ADF intake with CS0 having the least NDF and ADF intake followed by the other three treatments which were similar (P < 0.01). Digestibility of both NDF and ADF was greatest for CS0, followed by the other three treatments which were similar (P <0.01). There was a linear decrease in digestibility as silage level increased (P < 0.01). Digestible energy (Mcal/lb) was greatest for CS0 (P < 0.01) and lesser but not different between Alf, CS7.5 and CS15. There was a tendency (P = 0.15) for DE intake (Mcal/d) to be greatest in cattle fed CS7.5 followed by CS0, CS15 and Alf treatments. There was no difference for *in situ* NDF digestibility on bran incubated for 24 hours across diet treatments (P = 0.94).

Cattle on all treatments consumed the same amount of meals, with the same meal size, and ate the same proportion as a total of their daily DMI at each meal (Table 2; P = 0.60). However, cattle fed CS0 and Alf spent the most time eating, and linearly decreased time spent eating when corn silage inclusion increased to 15% (P = 0.10). Similarly, cattle fed CS0 had a slower rate of intake per hour of time spent eating and linearly increased as silage inclusion increased (P = 0.04).

Average daily pH, minimum, and maximum pH linearly increased with increasing silage inclusion (P < 0.01; Table 3). Steers fed Alf had similar average, minimum, and maximum pH to steers fed CS15. There was a quadratic increase in magnitude and linear increase in variation of pH with increasing inclusions of silage (P < 0.05). Steers fed Alf had similar magnitude and variation as both CS7.5 and CS15. Maximum and minimum pH was least, but magnitude was also less for CS0 compared to CS7.5, CS15 or Alf.

Steers that received the CS0 treatment had increased time with ruminal pH below 5.6 and 5.3 and greater area below the curve for both 5.6 and 5.3 (P < 0.01). Animals fed CS0 spent over 19.7 hours in subacute acidosis (pH < 5.6) and 13.7 hours in acute acidosis (pH < 5.3). This is compared to 6.7 for both subacute and acute acidosis for animals fed the CS15 treatment. There was a linear decrease in time spent below 5.6

Table 3. Ruminal pH characteristics for steers fed corn silage at two levels as a roughage source compared to no roughage or an alfalfa control.

	Treatment[1]					*P*–value[3]		
Item[2]	Alf	CS0	CS7.5	CS15	SEM	F-test	Linear	Quadratic
Minimum	4.96^{ab}	4.78^{c}	4.86^{bc}	4.98^{a}	0.04	< 0.01	< 0.01	0.81
Maximum	6.47^{a}	6.09^{b}	6.39^{a}	6.48^{a}	0.06	< 0.01	< 0.01	0.15
Average	5.52^{ab}	5.29^{c}	5.42^{b}	5.58^{a}	0.05	< 0.01	< 0.01	0.83
Magnitude	1.51^{a}	1.32^{b}	1.53^{a}	1.50^{a}	0.06	0.03	0.02	0.09
Variation	0.124^{a}	0.087^{b}	0.125^{a}	0.127^{a}	0.014	0.16	0.05	0.31
Time < 5.6, min/d	911^{bc}	1184^{a}	1030^{ab}	814^{c}	67	< 0.01	< 0.01	0.71
Area < 5.6	296^{bc}	505^{a}	399^{ab}	255^{c}	52.1	< 0.01	< 0.01	0.77
Time < 5.3, min/d	480^{bc}	821^{a}	658^{ab}	407^{c}	90.7	< 0.01	< 0.01	0.60
Area < 5.3	83^{b}	200^{a}	141^{ab}	73^{b}	31.1	0.01	< 0.01	0.90

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

[1]Treatments included Alf: Alfalfa included at 7.5% of diet DM; CS0: contained no corn silage or alfalfa; CS7.5: corn silage included at 7.5% of diet DM; CS15: corn silage included at 15% of diet DM.

[2]Average pH over 4 days; Time × Day was not significant (*P* > 0.58)

[3]F-test comparing all 4 treatments, linear and quadratic effects of silage inclusion

Table 4. Concentration of VFA for ruminal fluid collected from steers fed corn silage at two levels as a roughage source compared to no roughage or an alfalfa control.

	Treatment[1]					*P*–value[3]		
Item[2]	Alf	CS0	CS7.5	CS15	SEM	F-test	Linear	Quadratic
Propionate, %[4]	36.0^{c}	44.2^{a}	39.6^{b}	37.2^{c}	3.04	<0.01	0.02	<0.01
Acetate, %	47.3	40.8	46.6	48.8	4.87	0.12	0.6	0.02
Butyrate, %	10.1	7.80	7.72	8.70	1.1	0.1	0.36	0.11
Total VFA, mM	98^{bc}	119^{a}	108^{ab}	86^{c}	7.8	<0.01	0.15	<0.01
A:P ratio[5]	1.38^{a}	0.84^{c}	1.18^{b}	1.31^{ab}	0.18	<0.01	<0.01	<0.01

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

[1]Treatments included Alf: Alfalfa included at 7.5% of diet DM; CS0: contained no corn silage or alfalfa; CS7.5: corn silage included at 7.5% of diet DM; CS15: corn silage included at 15% of diet DM.

[2]Average concentration over 4 time points (0800 h, 1000 h, 1200 h, 1400 h); Time x Trt was not significant (*P* > 0.34)

[3]F-test comparing all 4 treatments, linear and quadratic effects of silage inclusion

[4]Percent of total VFA

[5]Acetate to propionate ratio

and 5.3 with an increase in silage inclusion (*P* < 0.01). The area under 5.6 and 5.3 also linearly decreased with increasing silage inclusion. Steers fed Alf had parameters, time and area below 5.6 and 5.3, which were more similar to CS15 than CS7.5.

Collected from rumen fluid (Table 4), molar concentrations of total VFA were greatest for CS0, followed by CS7.5 and Alf, and CS15 having the lowest concentration of total VFA (*P* < 0.01). Propionate concentration was greatest for CS0 (44.2%), followed by Sil 7.5 (39.6%), and least for Alf (36.0%) and CS15 (37.2%; *P* < 0.01). Acetate and butyrate concentrations were not significantly different among treatments (*P* ≥ 0.10). The A:P ratio was greatest for Alf (1.38) and CS15 (1.31) followed by CS7.5 (1.18) and least for CS0 (0.84; *P* <0.01). Steers fed Alf had similar propionate and total VFA concentrations to CS15 compared to CS7.5.

Conclusion

Results suggest that decreasing inclusion of silage increased the concentration of VFA and lowered ruminal pH, increasing potential risk for acidosis. Animals fed 15% corn silage had similar ruminal pH to animals fed 7.5% alfalfa and spent less time in subacute and acute acidotic conditions. Feeding 15% corn silage also yielded similar VFA concentrations to feeding alfalfa hay. Therefore, potential for acidosis is significantly decreased with increased pH, mitigating risk for digestive upset or death when steers are fed 15% corn silage.

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Effects of Varying Levels of Silage Inclusion and Brown Midrib Corn Silage on Finishing Performance of Steers

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Summary with Implications

A 2 × 3 factorial finishing study evaluated traditional or brown midrib corn silage fed at three inclusions in finishing diets. Silage inclusion was 15%, 45%, or 75% inclusion (DM basis) for 70 days followed by 15% inclusion for the remainder of the finishing phase. Cattle were ultrasounded twice to calculate backfat deposition rate for a target backfat of 0.55 inches, as cattle were fed longer if silage inclusion was 45 or 75/15%. Cattle fed 45% or 75/15% silage inclusion had greater final body weight (BW) and days on feed, but higher feed:gain (F:G) than cattle fed 15% silage. Daily gain was greatest for cattle fed 15% silage, but not different between cattle fed 45% and 75/15% treatments. Cattle fed 45% and 75/15% silage had greater final hot carcass weight (HCW) and longissimus muscle (LM) area than 15% but fed for 28 additional days. Dry matter intake was greater for cattle fed brown midrib (bm3) silage but gain or F:G were not affected. Backgrounding cattle on a low energy diet followed by a high energy diet resulted in similar growth performance and carcass endpoint as cattle fed a consistent inclusion of silage throughout the entirety of the feeding period. Feeding cattle 45% or 75/15% silage resulted in larger carcass weights and more days on feed (DOF) than cattle fed 15% silage for the finishing period. This resulted in greater returns for cattle fed 45% and 75/15% silage diet as compared to cattle fed a high energy 15% silage diet throughout the feeding period.

Introduction

Cattle feeders typically feed higher inclusions of corn silage in the growing phase in the feedlot, while decreasing to a low inclusion for the finishing phase. Increasing corn silage inclusion in the diet has been evaluated and showed economic benefit, despite lower average daily gain (ADG), specifically when distillers grains were included in the diet (*2015 Nebraska Beef Cattle Report*, pp. 66–67). Brown midrib hybrids of corn silage have a lower lignin concentration resulting in improvement of fiber digestibility (*2019 Nebraska Beef Cattle Report*, pp. 72–75; *2018 Nebraska Beef Cattle Report*, pp. 89–91). Feeding brown midrib corn silage hybrids at 40% in feedlot finishing diets resulted in greater ADG and HCW compared to corn silage hybrids without a brown midrib trait *(2018 Nebraska Beef Cattle Report*, pp. 89–91). The objective of this study was to determine if including brown midrib or conventional corn silage at greater than typical inclusion of 15% in the feedlot diet affected growth and economic performance as compared to cattle fed a typical backgrounding then finishing diet.

Procedure

Corn silage was harvested at the Eastern Nebraska Research and Education Center (ENREC) near Mead, Nebraska, between September 2 and 12, 2016. Corn silage harvest was targeted to be initiated when the field was approximately ¾ milkline and 37% DM. The two corn silage hybrids (Mycogen® seeds) utilized were a standard control (CON; hybrid TMF2H708), and a brown midrib hybrid (*bm3*; hybrid F27F627). Corn silage was kernel processed at harvest with an onboard kernel processor set at 2mm and a 0.75-inch length of cut. Dry matter samples were taken from each truckload of corn silage and dried in a 60°C (140°F) forced-air oven for 48h to determine dry matter (DM) of the silage at harvest. Silages were stored in bunker silos and opened at the initiation of the trial in February of 2017 and were sampled for fermentation analysis of acid and pH profile and DM (forced air oven at 60°C for 48 hours). All feeds were sampled weekly for DM, and monthly composites were analyzed for nutrient composition.

Crossbred steers (n=288; initial BW 700 ± 6.6 lb) were sorted into 2 BW blocks and assigned randomly to one of 36 pens (8 steers/pen; 1 replication heavy block, 5 replications light block). All steers were limit-fed a common diet of 50% alfalfa hay and 50% SweetBran® (DM basis) at 2% of BW for 5 days before initiation of the trial to minimize gastrointestinal fill. Initial BW was measured on two consecutive days (d0 and d1) and averaged. Steers fed the 15% corn silage inclusion were stepped down from a high forage diet over 24 days and four steps, beginning with 30% inclusion of alfalfa and stepping down to 0% alfalfa while increasing corn grain inclusion. Steers fed 45% inclusion were stepped down to 45% inclusion of silage over 10 days and three steps. Cattle fed 75/15% treatment were stepped down to 15% silage on d70 using the same adaptation steps as used with the 15% silage treatment. Treatments were arranged as a 2×3 factorial, that consisted of corn silage hybrid (*bm3* or CON) and varying inclusions in the final diet, 15%, 45% or 75/15% (Table 1). All steers were fed Rumensin® (Elanco Animal Health) at 30 g/ton of DM and Tylan® (Elanco Animal Health) at 8.8 g/ton of DM. Steers were initially implanted with Synovex Choice® (Zoetis) on d1, and reimplanted with Synovex Choice® (Zoetis) on d70. All diets were fed once daily, and refusals were assessed at approximately 0530 each morning aiming for a small scattering of feed left in the bunk each morning. Feed refusals were subsampled and dried for 48 hrs in a 60°C oven to calculate for DM refused. Steers were ultrasounded for backfat thickness on d70 and d126/127. Backfat deposition rate was calculated from these values to determine slaughter dates at a target backfat thickness of 0.55 inches. Cattle were slaughtered at

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Table 1. Diet composition (DM Basis) for beef cattle fed two corn silage hybrids at three different levels of inclusion in the feedlot diet

	15		45		75/15	
Item[1]	*bm3*	Control	*bm3*	Control	*bm3*	Control
CON Corn Silage		15.0		45.0		75.0
bm3 Corn Silage	15.0		45.0		75.0	
Dry-rolled corn	30.0	30.0	15.0	15.0	-	-
High Moisture Corn	30.0	30.0	15.0	15.0	-	-
WDGS	21.0	21.0	21.0	21.0	21.0	21.0
Supplement[2]	4.0	4.0	4.0	4.0	4.0	4.0

[1] Treatments were control (CON; hybrid TMF2H708), and a brown midrib hybrid (*bm3*; hybrid-F27F627), cattle fed 75/15 treatment were fed 75% corn silage diet for the initial 70 days on feed, followed by 15% for the remainder of the feeding period.

[2] Supplement formulated to be fed at 4% of diet DM, Supplement consisted of 1.1% fine ground corn, 1.64% limestone, 0.10% tallow, 0.75% urea, 0.30% salt, 0.05% trace mineral package, 0.015% Vitamin A-D-E package as a percentage of the final diet. It was also formulated for 30 g/ton Rumensin®(Elanco Animal Health, DM Basis) and 8.8 g/ton Tylan® (Elanco Animal Health, DM basis).

Table 2. Nutrient and fermentation analysis of silage hybrids[1]

Item	*bm3*	Control
DM, %[2]	33.23	30.67
CP, %	6.27	7.87
NDF, %	33.3	38.4
ADF, %	22.2	24.6
Starch, %	38.3	37.9
pH	4.33	4.90
Lactic acid, %	2.69	2.93
Acetic acid, %	3.38	4.29
Propionic acid, %	0.54	0.69
Butyric acid, %	0.11	0.11
Total Acids, %	6.85	6.38

[1] Treatments were control (CON; hybrid-TMF2H707, a brown midrib hybrid (*bm3*; hybrid-F27F627),

[2] DM was calculated using weekly samples and oven dried for 48 h at 60°C.

Note: Fermentation analysis was conducted on bi-monthly composite silage samples and analyzed at Dairyland Labs (St. Cloud, MN).

a commercial abattoir (Greater Omaha, Omaha, NE). Steers on the 15% silage inclusion were fed for 153 days before harvest, while steers fed 45 and 75/15% inclusion diets were fed for 181 days before harvest. On the day of harvest, liver scores and HCW were recorded. Carcass-adjusted final body weight (using a 63% dressing percentage) from the HCW were used to determine ADG and feed conversion. Carcass characteristics included marbling score, 12th rib fat thickness and LM area, which were recorded after a 48-h chill.

Economics were evaluated using a corn silage pricing application from Iowa State University accounting for silage shrink (15% DM basis), manure value of spreading the manure 1 year in four to replace the silage removal of phosphorus, incurring one fourth the credit for manure and one fourth hauling expenses, and the opportunity cost of corn grain and stover removal. Manure value was calculated using BFNMP$ system for cattle fed a 45% silage-based diet with 21% WDGS. Initial purchase price was calculated using the average initial purchase weight of a pen multiplied by the average price/lb to get a net return of $0/head for cattle on the 15% silage treatment. Cattle interest charges were 7.5%, with a $200 down deposit on cattle over their feeding period (DOF/365). Corn was priced on market prices for September, with an additional $2.17/ton DM for processing costs. Feed interest costs were 7.5%. Supplement including monensin and tyolosin was $300/ton (DM basis) with 1% shrink applied, WDGS was 90% the price of corn (DM basis) with a 5% shrink applied. Medicinal and processing charges were $20/head and yardage was charged to $0.50/hd/day.

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. Liver scores were analyzed as a binomial distribution using PROC GLIMMIX procedures of SAS. The treatment design was a 2 × 3 factorial, and data were analyzed for an interaction to determine simple effects of inclusion of corn silage and corn silage hybrid, and main effects of each factor were analyzed if there were no significant interactions reported.

Results

Fermentation analyses (Table 2) show the 6 silage samples had a pH at or below 4.9 and lignin at 2.6% for control and 2.4% for *bm3*. Acid detergent fiber, the cellulose and lignin portion of the plant, was numerically lower for *bm3* silages compared to the CON. Neutral detergent fiber was greater for CON silage samples as compared to *bm3*. Crude protein was lower 6.27% for *bm3* silage as compared to CON at 7.87%.

Corn Silage Level

There were no interactions between corn hybrid and corn silage inclusion for growth performance and carcass characteristics evaluated ($P \geq 0.26$). There were no interactions ($P > 0.08$) were observed for carcass characteristics measured. For the main effects of corn silage inclusion (Table 3), cattle fed silage at 45 and 75/15% inclusion had greater final BW and HCW ($P < 0.01$), with no differences between 45 and 75/15% inclusion treatments ($P > 0.06$). The cattle fed 45% and 75/15% corn silage were fed for 28 additional days than those fed 15%. Cattle fed 15% corn silage inclusion had greater ADG ($P < 0.01$) than cattle fed the 45% and 75/15% treatments ($P = 0.09$). Feed conversion was lowest for 15% corn silage inclusion ($P < 0.01$) compared to both 45% and 75/15% silage inclusion, which were not different ($P = 0.84$). Backfat thickness was greatest for 45% inclusion silage (0.60 in), lowest for 15% inclusion (0.53 in; $P < 0.05$), with 75/15% inclusion being intermediate (0.55 inches; $P = 0.13$). Dry matter intake was greater ($P = 0.01$) for 15% and 45% silage inclusion (23.7 and 23.6 lb/day, respectively) versus 23.0 lb/day in the 75/15% inclusion. The lack of statistical difference between the 45% and 75/15% silage fed groups in terms of growth performance or carcass characteristics suggests cattle fed for a short backgrounding phase followed by a typical finishing phase were similar in growth to cattle fed a consistent diet throughout the feeding period.

When the 15% treatment was equal to a net return of $0.00, cattle fed the 45% corn silage treatment had an overall profit of $43.41/hd ($P < 0.01$) over the cattle fed 15% silage diets for 153 days. The cattle fed 75/15% had a tendency to have a greater

Table 3. Main effect of corn silage inclusion on cattle performance and carcass characteristics.

	Treatment^{1}				
Item	15	45	75/15	SEM	*P*-Value^{2}
Pens	12	12	12		
Days on Feed	153	181	181		
Performance					
Initial BW, lb	700	700	699	1.2	0.61
Carcass Adjust BW, lb^{3}	1315^{a}	1393^{b}	1374^{b}	7.3	<0.01
Final Shrunk BW, lb^{4}	1321^{a}	1423^{b}	1402^{b}	6.8	<0.01
DMI, lb/day	23.7	23.6	23.0	0.22	0.01
ADG, lb^{3}	4.02^{a}	3.82^{b}	3.73^{b}	0.17	<0.01
Feed:Gain^{3}	5.88^{a}	6.18^{b}	6.17^{b}	-	<0.01
Returns, $/hd	0.03^{a}	43.41^{b}	27.06^{b}	7.18	<0.01
Carcass Characteristics					
HCW, lb	829^{a}	877^{b}	866^{b}	6.2	<0.01
Dressing Percentage	62.73^{a}	61.65^{b}	61.75^{b}	0.242	<0.01
LM Area, in^{2}	13.13^{a}	13.51^{ab}	13.64^{b}	0.16	0.05
Marbling Score^{5}	460	480	473	10.5	0.33
Backfat Thickness, in	0.53^{a}	0.60^{b}	0.55^{ab}	0.02	0.06
Liver Abscesses, %^{6}	6.25	2.08	3.13	-	-

[a,b] Means with different superscripts differ ($P < 0.05$).

[1] Treatments were 15% silage inclusion, 45% silage inclusion, and 75 to 15% silage inclusion

[2] *P*-value for the main effect of corn silage inclusion

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

[4] Final shrunk body weight calculated from pen weights taken before transport to slaughter plant, with 4% pencil shrink applied

[5] Marbling Score 400-Small^{00}, 500 = Modest^{00}

[6] Liver abscess data did not converge

Table 4. Main effect of corn silage hybrid on growth performance and carcass characteristics

	Treatment^{1}			
Item	*bm3*	Control	SEM	*P*-value^{2}
Pens, n	18	18		
Performance				
Initial BW, lb	700	699	1.0	0.39
Carcass Adjust BW, lb^{3}	1366	1355	6.3	0.16
Final Shrunk BW, lb^{4}	1384	1380	5.9	0.58
DMI, lb/day	23.7	23.1	0.15	<0.01
ADG, lb^{3}	3.89	3.83	0.04	0.18
Feed:Gain^{3}	6.10	6.02	-	0.23
Returns, $/hd	25.64	21.36	6.16	0.57
Carcass Characteristics				
HCW, lb	861	854	4.0	0.16
Dressing Percentage	62.19	61.89	0.21	0.24
LM Area, in^{2}	13.36	13.50	0.14	0.39
Marbling Score^{5}	477	466	9.0	0.34
Backfat Thickness, in	0.58	0.54	0.02	0.05
Liver Abscesses, %^{6}	2.78	4.86	-	-

[1] Treatments were brown midrib corn silage (*bm3*-Hybrid-F27F627) or Control corn silage (CON; hybrid-TMF2H708)

[2] *P*-Value for the main effect of corn silage hybrid

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

[4] Final shrunk body weight calculated from pen weights taken before transport to slaughter plant, with 4% pencil shrink applied

[5] Marbling Score 400 = Small^{00}, 500 = Modest^{00}

[6] Liver abscess data did not converge

($P < 0.01$) net profit of $27.06/hd over 15% silage fed cattle. No difference in profitability was observed ($P = 0.08$) between the 45% and 75/15% fed cattle.

Corn Silage Hybrid

There were no differences in growth performance between the two hybrids of corn silage used in this trial (Table 4). Daily dry matter intake was greater ($P = 0.01$) for *bm3* fed steers compared to control steers. This did not translate into improvements for ADG or F:G ($P = 0.18$). Backfat thickness was greater for steers fed *bm3* silage over control as well (0.58 inches vs. 0.54 inches; $P = 0.05$), but no other carcass characteristics were affected by corn silage hybrid. Corn silage hybrid did not affect ($P = 0.57$) the average returns per animal, which averaged $25.64/hd for *bm3* and $21.36/hd for CON as compared to 15% silage inclusion.

Conclusion

Cattle fed 45% silage inclusion throughout the feedlot finishing phase performed similar to cattle fed 75 then 15% corn silage throughout the finishing phase. Increasing corn silage in the diet from 15 to 45% resulted in poorer growth performance but larger carcass size when finished to a common endpoint. Additionally, backgrounding cattle for a period then following with a high energy diet resulted in similar performance and carcass endpoint to cattle fed a consistent level of corn silage throughout the entirety of the feeding period. A consistently high silage finishing diet of 45% appears to be profitable for producers even when considering the extra days on feed as compared to cattle fed a low silage diet (15%). Utilizing a 45% silage diet appears to be as economical as backgrounding then finishing cattle to a common carcass endpoint. Feeding silage with the *bm3* trait did not affect ADG, feed conversion or carcass characteristics in this study.

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Effects of Brown Midrib Corn Silage Hybrids with or without Kernel Processing at Harvest on Nutrient Metabolism in Beef Steers

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Summary with Implications

A 2 × 3 factorial digestion study evaluated three corn silage hybrids and kernel processing for finishing steers. The three hybrids included a control corn silage, a brown midrib, and a brown midrib with a softer endosperm. Both brown midrib hybrids had greater fiber digestibility than the traditional control corn silage hybrid. No differences were observed between brown midrib hybrids for all other nutrients. Cattle fed brown midrib hybrids had a lower average ruminal pH compared to the control suggesting more fermentation, but no differences in volatile fatty acid concentration or proportions. Kernel processing had no effect on apparent total tract nutrient digestibility for any nutrients measured in this study. Kernel processing did not impact any ruminal characteristics or metabolism by beef steers. In finishing diets including elevated levels of corn silage, brown midrib corn silage hybrids allow for improved fiber digestibility and more energy available to the animal for improved growth performance over cattle fed control corn silages. Kernel processing did not appear to affect any ruminal fermentation and digestibility parameters, despite an observed improvement in feed efficiency in a similar finishing trial.

Introduction

Corn silage has been a useful ingredient for producers because of it utilizes the entire plant, provides a year-round feed source, and delivers both roughage and energy (*2013 Nebraska Beef Cattle Report*, pp.74–75). A drawback of corn silage is its high lignin content, which may limit energy intake through gut fill. Improving fiber digestibility is beneficial as it allows for increased DMI in high-forage diets, and subsequent gain. Brown midrib hybrids of corn silage have a lower lignin concentration resulting in improved fiber digestibility (*2018 Nebraska Beef Cattle Report*, pp. 49–51). Some research indicates kernel processing at harvest may improve corn silage starch digestibility, presumably by reducing kernel size and increasing surface area for ruminal microbes. However, despite the fact starch digestibility is improved, a reduction in fiber digestibility has been observed, negating the positive effects of the kernel processing, resulting in no overall change in DM digestibility. Research is needed to determine if performance improvements are due to improved fiber digestibility of *bm3* hybrids in beef cattle finishing diets and if kernel processing plays a role in beef cattle finishing diets. The objective of this experiment was to determine whether kernel processing improved digestibility of a diet containing 40% of conventional or brown midrib corn silage.

Table 1. Diet composition (DM Basis) for beef cattle fed three different corn silage hybrids[1] that had been kernel processed (+KP) or not (-KP)

	CON		*bm3*		*bm3*-EXP	
Item	-KP	+KP	-KP	+KP	-KP	+KP
CON Corn Silage	40.0	40.0				
bm3 Corn Silage			40.0	40.0		
bm3-EXP Corn Silage					40.0	40.0
Modified distillers grains	30.0	30.0	30.0	30.0	30.0	30.0
Dry-rolled corn	25.0	25.0	25.0	25.0	25.0	25.0
Supplement[2]	5.0	5.0	5.0	5.0	5.0	5.0

[1] Treatments were control (CON; hybrid-TMF2H708), a *bm3* hybrid (*bm3*; hybrid-F15579S2), and an experimental *bm3* hybrid (*bm3*-EXP; hybrid-F15578XT) with a softer endosperm

[2] Supplement formulated to be fed at 5% of diet DM, Supplement consisted of 2.98% fine ground corn, 1.50% limestone, 0.125% tallow, 0.30% salt, 0.05% trace mineral package, 0.015% Vitamin A-D-E package as a percentage of the final diet. It was also formulated for 30 g/ton Rumensin®(Elanco Animal Health, DM Basis) and 8.8 g/ton Tylan® (Elanco Animal Health, DM basis).

Procedures

Corn silage was harvested at the Eastern Nebraska Research and Education Center (ENREC) near Mead, Nebraska, between September 2 and 12, 2016. Corn silage harvest was initiated when the field was approximately ¾ milkline and 37% DM. The three hybrids (Mycogen® seeds) utilized were a control (CON; hybrid TMF2H708), a brown midrib hybrid (*bm3*; hybrid F15579S2), and Unified™ corn silage with SilaSoft™ kernel technology brown midrib silage with a floury endosperm (*bm3*-EXP; hybrid-F15578XT). Dry matter samples were taken from each truckload of corn silage and dried in a 60°C forced-air oven for 48 h to determine DM of the silage at harvest. Each corn silage hybrid was split into two within the field, one being chopped to 0.75 in chop length with 2 mm kernel processing, and the other chopped at 0.75 in chop length, with no kernel processing. Silages were stored in sealed AgBags® and opened after 21 d. Silage was sampled for fermentation analysis and dry matter DM (forced air oven at 60°C (140°F), 48 h). All feeds were sampled weekly for DM, and monthly composites were analyzed for nutrient composition.

Six ruminally cannulated beef steers (1148 ± 88 lb) were utilized in a 6 × 6 Latin square with six 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

Table 2. Nutrient and fermentation analysis of silage hybrids[1]

	CON		*bm3*		*bm3*-EXP	
Item	-KP	+KP	-KP	+KP	-KP	+KP
DM[2]	38.58	35.35	34.85	34.43	35.80	35.96
CP	8.17	8.16	9.41	8.67	8.63	8.50
NDF, %	43.4	44.3	45.6	44.9	46.2	47.3
ADF, %	33.5	33.1	32.2	30.3	32.7	30.4
Starch, %	33.1	34.1	30.2	32.1	29.8	31.4
pH	3.8	4.1	4.2	4.2	4.0	9
Lactic acid, %	5.55	3.10	2.27	2.10	3.85	5.27
Acetic acid, %	0.87	3.75	5.16	5.02	3.50	2.66
Propionic acid, %	0.00	0.34	0.87	0.83	0.55	0.22
Butyric acid, %	0.00	0.00	0.00	0.00	0.00	0.00
Total Acids, %	6.42	7.19	8.31	7.95	7.89	8.16

[1] Treatments were control (CON; hybrid-TMF2H708), a *bm3* hybrid (*bm3*; hybrid-F15579S2), and an experimental *bm3* hybrid (*bm3*-EXP; hybrid-F15578XT) with a softer endosperm, and not kernel processed (-KP) and kernel processed (+KP)

[2] DM was calculated using weekly samples and oven dried for 48 h at 60°C.

Note: Fermentation analysis was conducted only on d 21 silage samples. All other analyses (DM, CP, NDF, ADF, starch) are based on composites of weekly samples taken during the finishing trial, and analyzed at Dairyland Labs (St. Cloud, MN).

Table 3. Main effect of corn silage hybrid on digestibility of cattle fed corn silage-based finishing diets

	Treatment[1]				
	Control	*bm3*	*bm3*-EXP	SEM	*P*-Value[2]
Dry Matter					
Intake, lb/d	22.2	23.4	21.7	0.63	0.17
Digestibility, %	64.6	66.1	68.0	1.10	0.12
Organic Matter					
Intake, lb/d	21.0	22.0	20.4	0.59	0.19
Digestibility, %	67.5^{a}	69.0^{ab}	71.1^{b}	1.085	0.08
NDF					
Intake, lb/d	6.4	6.8	6.5	0.20	0.33
Digestibility, %	45.5^{a}	54.4^{b}	58.2^{b}	1.88	<0.01
ADF					
Intake, lb/d	4.2	4.1	3.8	0.12	0.12
Digestibility, %	47.6^{a}	54.2^{b}	55.9^{b}	2.27	0.04
Starch					
Intake, lb/d	7.9	7.9	7.4	0.20	0.11
Digestibility, %	88.5	89.5	90.5	1.12	0.47
Energy					
Gross Energy Intake, Mcal	46.42^{a}	50.04^{b}	46.28^{a}	1.333	0.10
DE, Mcal/d	30.93^{a}	34.6^{b}	32.69^{ab}	1.045	0.07
DE, Mcal/lb intake	1.39^{a}	1.48^{b}	1.50^{b}	0.109	0.01
TDN, %	70.2^{a}	73.8^{b}	75.7^{b}	1.11	0.01

[a,b] Means with different superscripts differ ($P < 0.10$).

[1] Treatments were control (CON; hybrid-TMF2H708), a *bm3* hybrid (*bm3*; hybrid-F15579S2), and an experimental *bm3* hybrid (*bm3*-EXP; hybrid-F15578XT) with a softer endosperm

[2] *P*-value for the main effect of corn silage hybrid

each dietary treatment for six, 21-d periods, each with a 14-d adaptation followed by a 7-d collection period. Diets (Table 1) were mixed twice weekly and stored in a cooler (0°C) to ensure fresh feed for animals. The diet supplement was formulated to provide 30 g/ton of DM monensin (Rumensin: Elanco Animal Health) and 8.8 g/ton of tylosin (Tylan; Elanco Animal Health). Steers were dosed with 5 g/steer of titanium dioxide inserted through the rumen cannula twice daily at 0800 and 1600 h initiated on d-7 of each period. Fecal grab samples were collected at 0700, 1100, 1500, and 1900 h on days 17 to 20 of each period. Fecal samples were composited on a wet basis into a daily composite, freeze dried, and composited by steer within each period. Samples were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), organic matter (OM), starch, and titanium concentration. Orts were removed daily and dried for 48 h in a 60°C forced-air oven to determine dry matter intake. Feed offered and refused were analyzed for DM, OM, NDF, ADF, starch and lignin percentage. Ruminal pH was recorded every minute using wireless pH probes from days 15 to 21. Rumen fluid samples were collected on day 20 of each collection period at 0800, 1100, 1400, 1700 and 2000 h for ruminal VFA analysis.

Apparent total tract digestibility of the diets and total nutrient intake were analyzed using the MIXED procedure of SAS, with period and treatment considered fixed effects, and steer nested within period used as a random effect. Ruminal pH parameters were analyzed using the GLIMMIX procedure of SAS. *P*-values below 0.10 were considered significant.

Results

The six silage samples that underwent fermentation analyses had a pH of less than 4.2, and total acids in the silage were greater than 6.4% (Table 2). Acid detergent fiber, the cellulose and lignin portions were numerically lower for *bm3* and *bm3*-EXP silages as compared to CON (Table 2).

Corn Silage Hybrid

There were no interactions between corn silage hybrid and kernel processing on nutrient digestibility ($P > 0.14$). The effect of corn silage hybrid on apparent total tract nutrient digestibility are in Table 3. Organic matter digestibility was greater for *bm3*-EXP fed steers than CON fed steers ($P = 0.03$), with *bm3* as an intermediate between the two ($P \geq 0.17$). Neutral detergent fiber digestibility was greater for *bm3* and *bm3*-EXP compared to CON fed steers ($P < 0.01$), with no difference between the brown midrib hybrids ($P = 0.16$). Acid detergent fiber digestibility followed a similar trend to NDF digestibility. Acid detergent fiber digestibility was greatest for *bm3* and *bm3*-EXP over CON ($P < 0.05$), with no difference between the two brown midrib hybrids ($P = 0.60$). The improvement in fiber digestibility of the brown midrib hybrids was expected, as a decrease in lignin concentration was observed, allowing for more fiber to be available for microbial digestion, resulting in the improvement observed in OM digestibility. There was no difference in starch digestibility for the three hybrids ($P = 0.47$), which suggests the floury endosperm may not play a significant role in how that silage hybrid is utilized by the animal.

There were slight differences in energy intake between corn silage hybrids (Table 3). Gross energy intake (Mcal/day) was greatest for *bm3* ($P < 0.07$) with *bm3*-EXP and CON having similar gross energy intakes ($P = 0.94$). Digestible energy (Mcal/day) was greater ($P < 0.10$) for *bm3* compared with control, but was similar to *bm3*-EXP ($P = 0.21$). Steers fed CON had lower ($P < 0.10$) DE compared with *bm3,* but was similar to steers fed *bm3*-EXP ($P = 0.25$). Digestible energy per unit of dry matter intake (Mcal/lb) was greater for *bm3* and *bm3*-EXP ($P < 0.05$) compared to CON. Total digestible nutrients were greater ($P < 0.01$) for cattle fed *bm3* and *bm3*-EXP compared to CON. This is expected, as those animals fed the brown midrib hybrids had greater fiber digestibility, likely providing extra DE.

There were no differences ($P > 0.46$; Table 4) between the three corn silage hybrids for VFA concentration within the rumen. Acetate molar proportion averaged 57.4 mmol/100 mmol, and propionate averaged 27.7 mmol/100 mmol, resulting in an average A:P ratio of 2.45. This was not expected, as there were differences in fiber digestibility. Average ruminal pH was lower for the brown midrib hybrids ($P = 0.09$),

Table 4. Main effect of corn silage hybrid on VFA concentration and ruminal pH response variables of cattle fed corn silage-based finishing diets

	Treatment[1]				
	Control	*bm3*	*bm3*-EXP	SEM	*P*-Values[2]
VFA, mol/100 mol					
Acetate	57.5	55.3	59.5	33.14	0.65
Propionate	28.3	27.8	27.2	3.19	0.96
Butyrate	13.9	12.1	14.0	1.23	0.46
A:P Ratio	2.55	2.27	2.54	0.29	0.72
Ruminal pH Variable					
Maximum pH	7.06	6.80	6.75	0.1209	0.11
Average pH[3]	6.12[a]	5.89[ab]	5.83[b]	0.109	0.09
Minimum pH	5.17	5.00	4.86	0.130	0.21
Time below pH 5.6, min/day	270	435	562	122.13	0.19
Time below pH 5.0 min/day	2.9	26.0	36	14.256	0.19

[1] Treatments were control (CON; hybrid-TMF2H708), a *bm3* hybrid (*bm3*; hybrid-F15579S2), and an experimental *bm3* hybrid (*bm3*-EXP; hybrid-F15578XT) with a softer endosperm

[2] *P*-value for the main effect of corn silage hybrid

[3] Means with different superscripts differ ($P < 0.10$)

Table 5. Main effect of kernel processing on digestibility of cattle fed corn silage-based finishing diets

	Treatment[1]			
	-KP	+KP	SEM	*P*-Values[2]
Dry Matter				
Intake, lb/day	22.9	22.0	0.52	0.23
Digestibility, %	66.3	66.1	0.90	0.99
Organic Matter				
Intake, lb/day	21.6	20.7	0.48	0.21
Digestibility, %	69.2	69.2	0.89	0.96
NDF				
Intake, lb/day	6.7	6.4	0.17	0.18
Digestibility, %	52.5	52.9	1.53	0.86
ADF				
Intake, lb/day	4.1	3.9	0.10	0.13
Digestibility, %	52.6	52.5	1.85	0.95
Starch				
Intake, lb/day	7.9	7.5	0.16	0.13
Digestibility, %	89.0	89.9	0.91	0.49
Energy				
Gross Energy Intake, Mcal	48.9	46.3	1.09	0.11
DE, Mcal/day	33.7	31.8	0.85	0.11
DE, Mcal/lb intake	1.47	1.45	0.196	0.37
TDN, %	73.8	72.6	0.91	0.36

[1] Treatments were not kernel processed (-KP) and kernel processed (+KP).

[2] *P*-value for the main effect of corn silage hybrid

Table 6. Main effect of kernel processing on VFA concentration of cattle fed corn silage-based finishing diets.

	Treatment			
	-KP	+KP	SEM	*P*-Values
VFA, mol/100 mol				
Acetate	57.8	57.1	2.57	0.85
Propionate	29.5	25.9	2.93	0.37
Butyrate	13.1	13.6	1.01	0.69
A:P Ratio	2.38	2.52	0.251	0.67
Ruminal pH Variable				
Maximum pH	6.81	6.94	0.095	0.33
Average pH	5.94	5.95	0.080	0.88
Minimum pH	5.10	4.92	0.103	0.21
Time below pH 5.6, min/day	401	444	96.3	0.74
Time below pH 5.0 min/day	9.9	33.4	11.25	0.14

[1] Treatments were not kernel processed (-KP) and kernel processed (+KP).

[2] *P*-value for the main effect of corn silage hybrid

likely attributable to improved ruminal fermentation from improved fiber digestibility. A shift in average lower ruminal pH may have been due to an increase in VFA concentration but did not create a shift in VFA proportions observed in the rumen. Generally, in high fiber diets, greater acetate vs. propionate molar proportions are observed.

Kernel Processing

Kernel processing did not influence apparent total tract nutrient digestibility of any of the nutrients measured (Table 5; $P \geq 0.13$). This was unexpected, as there was an improved feed conversion due to kernel processing in a previous trial with identical diets (*2018 Nebraska Beef Cattle Report*, pp. 89–91). Additionally, there was no effect of kernel processing on dietary energy variables measured ($P \geq 0.11$). Digestible energy per pound of intake was 3.25 Mcal/lb and 3.20 Mcal/lb for non-kernel processed and kernel processed, respectively ($P = 0.37$). Total digestible nutrient content of the diet was not affected ($P = 0.36$) by kernel processing. Kernel processing did not affect ruminal VFA concentration (Table 6, $P \geq 0.37$). No differences were observed ($P \geq 0.14$) for any ruminal pH parameters measured due to kernel processing (Table 6). With no observable changes in digestion, ruminal pH or VFA concentration, the digestion trial results do not support the observed performance in the growth trial.

Conclusion

Feeding *bm3* and *bm3*-EXP corn silage hybrids improved OM digestibility, greatly improved NDF and ADF digestibility, with no appreciable difference in starch digestibility. In addition, DE intake per pound of DM intake was greater for *bm3* and *bm3*-EXP corn silage hybrids as well. No appreciable differences were observed due to kernel processing of silage hybrids on any metabolism response variable analyzed.

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A Comparison of Synovex ONE® Alone to Synovex Choice® Followed by Synovex Plus® as Implant Strategies for Finishing Heifers

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Summary with Implications

A commercial feedlot study utilizing 1,737 crossbred heifers (initial BW 690 lb) compared the effect of two implant strategies [Synovex ONE Feedlot (day 0) or Synovex Choice (day 0) followed by Synovex Plus (day 95)] on performance and carcass characteristics. No differences were observed in carcass weight, final body weight, or gain, but heifers implanted with Synovex ONE Feedlot had slightly greater feed conversion and greater intake than heifers implanted using Synovex Choice/Synovex Plus. Heifers implanted with Synovex Choice/Synovex Plus had lower marbling score and yield grade, higher dressing percentage, and greater loin muscle area compared to heifers implanted with Synovex ONE Feedlot. Cattle implanted with Synovex ONE Feedlot showed a tendency for better quality grading compared to heifers implanted with Synovex Choice/Synovex Plus. These data suggest that implanting heifers with Synovex ONE Feedlot gives comparable growth to heifers implanted with Synovex Choice followed by Synovex Plus, with some changes in fatness when fed equal days.

Introduction

The use of growth-promoting implants in both steers and heifers improves growth performance and lean meat yield when compared to unimplanted cattle. There are many different implant strategies common in the industry. With increased incentive to feed cattle to heavier weights, a dual-implant strategy with an implant given upon arrival and a terminal implant given later is common. The level of trenbolone acetate (TBA) and estradiol (E) or the estradiol analog estradiol benzoate (EB) provided in those implants determine the strength of the implant, with the highest concentration of TBA or E typically found in the terminal implant. Re-implanting cattle requires handling animals a second time. A single implant able to cover the entire feeding period may be appealing to producers that want to minimize labor costs or reduce handling. Synovex ONE Feedlot is a single implant that is coated with a polymer film that delivers a slow release of TBA and EB. This allows the implant to remain active up to 200 days. The objective of this study was to evaluate the effects of implanting heifers with Synovex ONE Feedlot compared to a dual implant strategy of Synovex Choice followed by Synovex Plus on finishing heifer performance and carcass characteristics.

Procedure

Crossbred heifers (n = 1737) weighing 690 lb of initial body weight (BW) were fed at a commercial feedyard in central NE (Ford Farms, Cairo, NE). Heifers were sourced from sale barns located in NE, KS, and OK. The study was designed as a randomized complete block design with blocking factor being arrival date and initial weight of the cattle and pen was replication. Treatments were (1) implanting with Synovex ONE Feedlot (200 mg of TBA + 28 mg EB; **ONE**) at initial processing and (2) implanting with Synovex Choice (100 mg TBA + 14 mg EB) at initial processing followed by Synovex Plus 95 days later (200 mg TBA + 28 mg EB; **CH+**). Heifers were randomly allotted to pen (n = 24) based on a BW randomization using pay weight. There were 12 replications started on trial over 9 dates. Treatments were assigned to pens within replication using a random number generator. Heifers were processed, weighed, and assigned to pen and treatment in one event. At initial processing, heifers received Inforce 3 (Zoetis), One Shot BVD (Zoetis), albendazole (Valbazen, Zoetis), doramectin (Dectomax, Zoetis), and an implant based on the assigned treatment. Also at processing, heifers were pregnancy checked using rectal ultrasound and if bred, were administered dinoprost tromethamine (Lutalyse HighCon, Zoetis) or both Lutalyse HighCon and dexamethasone to abort. Heifers that were aborted were not removed from the study. Re-implanting occurred between 93 and 95 days after initial processing for heifers assigned to the CH+ strategy. Heifers assigned to the ONE strategy were not processed after initial processing. Heifers were fed an average of 182 days.

Three intermediate diets were used to step up heifers onto a finishing diet containing 59.46% corn (dry rolled, high moisture, or a blend), 30% wet or modified distillers grains plus solubles (DGS), 3% alfalfa hay, 5% corn stalks, 2.5% supplement meal, 0.04% micro-ingredients on a dry matter (DM basis). All ration formulation changes were the same relative to days on feed for all cattle throughout the trial. Initial BW was defines as individual BW at processing, shrunk 4.0%. Final BW was collected at time of shipping using weights collected on the truck, then taking average pen weight shrunk 4.0% to adjust for gut fill. Cattle were harvested at a commercial facility on four dates and individual carcass data were collected. Individual hot carcass weight (HCW) was collected at slaughter. Following a 24 hr chill, 12th-rib fat depth, longissimus muscle (LM) area, marbling scores, USDA quality grade (QG), and USDA yield grade (YG) were collected.

Statistical analysis of performance and carcass data were conducted using the Mixed procedure of SAS (9.3, SAS Institute Inc, Cary, NC). Pen was the experimental unit. Treatment and block were considered fixed effects. All performance and carcass data were analyzed with initial BW as a covariant because of a very small yet sig-

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nificant difference between treatments for initial BW. Quality grade and yield grade distributions and morbidity and mortality data were analyzed using the Glimmix procedure of SAS. Treatment differences were significant at an α value equal to or less than 0.05.

Table 1. The effect of using one slow-release implant compared to a dual implant strategy on heifers fed 182 d

	Treatment[1]			
Item	ONE	CH+	SEM	*P*-Value
No. of heifers (pens)	869 (12)	868 (12)	-	-
Initial BW, lb	690	691	0.5	0.08
DMI, lb/d	23.6	23.3	0.11	0.09
Initial 96 d, lb/d[3]	21.8	22.1	0.16	0.34
Final 85 d, lb/d[3]	25.7	24.8	0.17	<0.01
Live Performance				
Final BW, lb[2]	1367	1366	3.1	0.90
ADG, lb/d	3.74	3.74	0.016	0.97
F:G	6.33	6.25	0.030	0.10
Carcass-adjusted performance				
Final BW, lb[4]	1362	1371	3.6	0.13
ADG, lb	3.72	3.76	0.019	0.13
F:G	6.37	6.21	0.028	<0.01
Carcass characteristics				
HCW, lb	846.0	851.8	2.19	0.11
Dressing Percentage, %	61.9	62.3	0.001	0.02
Marbling score	534.7	508.4	4.45	<0.01
LM area, in^2	13.2	13.6	0.07	<0.01
12th-rib fat thickness, in	0.772	0.750	0.01	0.15
Calculated Yield Grade	3.92	3.76	0.04	<0.01

[1]ONE = Synovex One Feedlot on d 0; CH+ = Synovex Choice on d 0 and Synovex Plus on d 95.

[2]Final BW is the average pen weight shrunk 4.0%. Subsequent ADG and G:F are calculated from shrunk final BW.

[3]These DMI figures are from before and after re-implanting dates for the CH+ treatment.

[4]Calculated as HCW divided by the mean dressing percentage of 62.13%. Subsequent ADG and G:F calculated using carcass-adjusted final BW.

Table 2. A comparison of the distribution of quality grade and calculated yield grade between heifers implanted with two different strategies

	Treatment[1]			
Item	ONE	CH+	SEM	*P*-Value
USDA Quality Grade, %			-	0.06
Prime	8.40	5.79	0.90	0.06
Upper 2/3 Choice	47.81	41.79	1.56	0.02
Low Choice	35.37	39.15	1.21	0.05
Select	8.42	13.27	0.71	<0.01
USDA Yield Grade, %			-	0.09
1	1.61	2.45	0.53	0.29
2	11.51	14.52	1.21	0.11
3	39.23	47.00	1.44	<0.01
4	38.48	29.11	2.38	<0.01
5	9.16	6.91	1.10	0.17

[1]ONE = Synovex One Feedlot on d 0; CH+ = Synovex Choice on d 0 and Synovex Plus on d 95.

Results

Heifers implanted using the ONE strategy had a tendency for greater ($P = 0.09$) DMI than those implanted with the CH+ strategy (Table 1) with heifers implanted using the CH+ strategy having significantly ($P < 0.01$) lower DMI in the final 85 days following re-implanting. No differences were observed between treatments for carcass-adjusted final BW, live final BW, live ADG, and carcass-adjusted ADG ($P \geq 0.13$). Heifers implanted using the CH+ strategy had lower ($P < 0.01$) F:G on a carcass-adjusted basis compared to those implanted with the ONE strategy, but similar ($P = 0.10$) F:G on a live basis. All heifers had similar ($P = 0.11$) HCW. Cattle implanted using the ONE strategy had greater ($P \leq 0.01$) marbling score and calculated YG than those implanted using the CH+ strategy. Heifers implanted with the CH+ strategy had greater ($P \leq 0.02$) dressing percentage and LM area than heifers implanted with the ONE strategy. Treatments had similar ($P = 0.15$) 12th rib fat thickness.

A tendency ($P = 0.06$) for a difference in QG distribution between treatments was observed (Table 2). Heifers implanted using the ONE strategy showed a tendency ($P = 0.06$) for greater percent of carcasses grading Prime and a greater ($P = 0.02$) percent of carcasses grading in the upper 2/3 of Choice. Furthermore, heifers implanted with the ONE strategy had a lower ($P = 0.05$) percent of carcasses grading in the lower 1/3 of Choice and a lower ($P < 0.01$) percent carcasses grading Select compared to cattle implanted with the CH+ strategy. The USDA Yield Grade distributions tended ($P = 0.09$) to be different between the two implant strategy treatments. Treatments did not differ ($P \geq 0.11$) in percent YG1 or YG2 carcasses but those implanted with the CH+ strategy had numerically greater percent YG1 and YG2 carcasses. Heifers implanted using the CH+ strategy had greater ($P < 0.01$) percent YG3 carcasses while those implanted with the ONE strategy had greater ($P < 0.01$) percent YG4 carcasses. Treatments were not different ($P = 0.17$) in percent YG5 carcasses but heifers implanted with the ONE strategy had numerically greater percent YG5 carcasses. No differences ($P \geq 0.38$) were observed between treatments for percent morbidity or mortality.

Conclusion

When fed to the same number of days, heifers implanted with the ONE strategy had greater intake but similar final weight and gain to heifers implanted with the CH+ strategy, resulting in slightly poorer feed conversion. Treatments had similar carcass weights and 12th rib fat thickness, but heifers implanted with the ONE strategy showed higher marbling scores and yield grade with lower dressing percentage and smaller loin muscle area. Heifers implanted with the ONE strategy showed an improvement in quality grade over heifers implanted with the CH+ strategy but had a higher percent yield grade 4 than cattle implanted with the CH+ strategy. No differences were observed between treatments in morbidity or mortality. These data suggest that utilizing Synovex ONE Feedlot in heifers can improve operational efficiency with minimal effect on performance.

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Evaluation of Reimplant Window with Revalor-200® on Steer Performance and Carcass Characteristics

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Summary with Implications

A feedlot study utilizing 800 crossbred steers (initial BW = 727 ± 55 lb) compared 5 different terminal implant (Revalor-200) times (160, 120, 100, 80, or 40 d prior to harvest) for steers fed 180 days on performance and carcass characteristics. All steers were implanted with Revalor-IS as an initial implant at trial initiation. Carcass-adjusted final BW, ADG, and F:G responded quadratically, with cattle implanted 80 to 120 d prior to harvest being the greatest. However, there was less than a 2% difference in performance between 120 and 80 days on terminal implant. Hot carcass weight responded quadratically, with no difference in fat thickness, rib eye area, marbling score, or calculated yield grade. When solved for the first derivative, all variables were maximized at 87 to 104 days on terminal implant when steers are fed for 180-d.

Introduction

In recent years, there has been much discussion on the ideal terminal implant window and the effect of re-implant time on finishing cattle performance and carcass characteristics. However, cattle are being fed longer and to heavier end points without facilities to handle larger cattle. The question becomes how early can cattle be re-implanted while still seeing advantages in performance. However, literature to define a terminal implant window is lacking, and most recommendations come from practical experience or closeout data from different groups of cattle. Therefore, the purpose of this experiment was to identify the optimum time on the terminal implant when steers are reimplanted with a Revalor-IS on arrival followed by Revalor-200 and fed for 180 d.

Procedure

A feedlot study was conducted at the University of Nebraska–Lincoln Eastern Nebraska Research and Extension Center (ENREC) near Mead. Crossbred yearling steers (n=800, initial BW = 727 ± 55 lb) were utilized in a generalized randomized block design with 2 initiation times, BW blocks within start times, and randomly assigned to pens (20 head/pen) within blocks. Pens were assigned randomly to 1 of 5 treatments (8 pens/treatment). Treatments included: 1) implanting with Revalor-200 (200 mg TBA + 20 mg E) on day 20 (160 days on terminal [DOT]); 2) Revalor-200 on day 60 (120 DOT); 3) Revalor-200 on day 80 (100 DOT); 4) Revalor-200 on day 100 (80 DOT); and 5) Revalor-200 on day 140 (40 DOT). All steers were implanted with Revalor-IS (80 mg TBA + 16 mg E) at initiation of the trial. Prior to the trial, steers were limit fed at 2% of BW with a 50% Sweet Bran (Cargill) and 50% alfalfa hay blend to limit BW variation due to gut fill. Steers were weighed on 2 consecutive days (day 0 and 1) to establish initial BW. All steers were adapted to a common finishing diet over a 24-d step-up period. The amount of wet distiller's grains, Sweet Bran, grass hay and supplement were held constant in the step-up diets (15%, 25%, 6% and 4%, respectively; DM-basis), while the amount of dry rolled corn was gradually increased replacing alfalfa hay. The finishing diet was identical across treatments and contained 50% dry rolled corn, 15% wet distiller's grains, 25% Sweet Bran, 6% grass hay and 4% supplement (DM-basis).

Individual BW was collected on days 0 and 1. Pen weights were collected for each pen on days 1, 20, 60, 80, 100, 140, and 180. Steers were weighed by replication, and once finished with each replication, steers that were to be re-implanted remained at the processing facility and other steers were returned to their home pen. Steers were harvested on day 180 at a commercial harvest facility (Greater Omaha, Omaha, NE). Prior to shipping, steers were offered 50% of the previous day's called feed. Final live BW was determined in the afternoon prior to shipping using the average pen weight shrunk by 4% to adjust for fill. Steers were then loaded onto trucks, transported to the abattoir, and harvested the following morning. Carcass-adjusted performance was calculated from HCW divided by a common dressing percent of 63%. At harvest, liver scores and HCW were recorded. After a 48-hour chill, 12th rib fat thickness, rib eye area, and USDA marbling score were recorded. Yield grade was calculated based on 12th rib fat thickness, rib eye area, HCW, and a constant kidney-pelvic-heart fat (KPH; 2.5%). Both performance and carcass data were analyzed in the MIXED procedure of SAS. The model included treatment, start time, block and block within start date as fixed effects and experimental unit was pen. Linear and quadratic orthogonal contrasts were evaluated for days on terminal implant. Alpha values of ≤ 0.05 were considered significant.

Results

Dry matter intake was the lowest for 40 DOT ($P \leq 0.04$, Table 1), with no differences between the other treatments ($P \geq 0.11$). Carcass-adjusted final BW responded quadratically ($P = 0.03$) with 100 DOT having the greatest final BW, but no differences between 100 or 120 DOT ($P = 0.82$). Carcass-adjusted ADG responded quadratically ($P = 0.02$), with 100 and 120 DOT being the greatest, but not different ($P = 0.87$) and 80 DOT being intermediate ($P \geq 0.57$). There was less than 1% difference in carcass-adjusted ADG between 120 DOT and 80 DOT. Carcass-adjusted F:G also responded quadratically ($P < 0.01$), with 160 DOT being the least efficient, but no

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Table 1. Effects of day on terminal implant (DOT; Revalor-200) following initial implant (Revalor-IS) on growth performance of steers fed for 180 d.

	Days on Revalor–200								
	160	120	100	80	40	SEM	F-Test	Linear	Quad
Live Performance									
Initial Weight, lb	726	727	728	728	727	3.1	0.70	0.41	0.96
Final Weight, lb[1]	1448	1469	1480	1470	1451	10.5	0.17	0.32	0.05
DMI, lb/d	26.1	26.3	25.9	25.8	25.2	0.21	0.01	0.18	0.93
ADG, lb	4.03	4.16	4.19	4.16	4.03	0.054	0.11	0.42	0.03
F:G[3]	6.45	6.33	6.17	6.21	6.25	-	0.04	0.90	0.01
Carcass Adjusted Performance									
Final Weight, lb[2]	1481	1508	1511	1501	1474	9.4	0.03	0.13	0.03
ADG, lb	4.21	4.37	4.36	4.34	4.16	0.049	0.01	0.18	0.02
F:G [3]	6.21	6.02	5.92	5.95	6.06	-	0.01	0.66	<0.01

[1] Pencil shrunk 4%. Subsequent ADG and F:G calculated from shrunk final BW

[2] Calculated by HCW divided by common dressing percentage of 63%. Subsequent ADG and F:G re-calculated from adjusted final BW

[3] Analyzed as G:F

Table 2. Effect of DOT (Revalor-200) following an initial implant (Revalor-IS) on carcass characteristics of steers fed for 180 d.

	Days on Revalor-200								
	160	120	100	80	40	SEM	F-Test	Linear	Quad
HCW	933	950	952	946	929	5.95	0.03	0.14	0.03
REA, sq in	13.7	14.0	14.2	13.8	13.9	0.08	<0.01	<0.01	0.09
Fat Thickness, in	0.65	0.64	0.64	0.64	0.63	0.015	0.81	0.66	0.97
Marbling Score[1]	517	530	541	534	534	7.5	0.27	0.60	0.11
Calc. Yield Grade[2]	3.79	3.72	3.69	3.77	3.64	0.060	0.38	0.52	0.89

[1] 400 = Small 00, 500 = Modest 00, 600 = Moderate 00

[2] Calculated using the following equation: 2.50 + (2.5 x 12th rib fat, in.) – (0.32 x REA, in^2) + (0.2 x 2.5 [KPH, %]) + (0.0038 x HCW, lb)

differences between other treatments ($P \geq 0.13$). Compared with 120 DOT, there was a 1.6% increase in F:G when cattle spent 100 DOT and a 0.5% increase in F:G compared to 80 DOT. There was a 1.2% improvement in F:G when steers spent 80 DOT compared with 120 DOT.

A quadratic response was observed for HCW ($P = 0.03$), with no differences between 80, 100 or 120 DOT ($P \geq 0.45$). There were no differences in backfat thickness ($P = 0.81$) and rib eye area decreased linearly with 100 and 120 DOT having the greatest rib eye area ($P \leq 0.05$). Marbling score and calculated yield grade were similar among treatments ($P \geq 0.27$).

Interim performance is summarized in Table 3. As expected, ADG and F:G were greater in most cases in each period following when the terminal implant was applied. The exception to this was when the 120 DOT treatment was applied. There were no differences in ADG or F:G between treatments ($P \geq 0.16$), but the respective treatment was not numerically greater compared to the other treatments. There was a tendency ($P = 0.06$) for ADG to be different among treatments when during d 82 to 101, however, 100 DOT was not the greatest despite those steers having received their terminal Revalor-200 on d 80. Due to DMI being the lowest for 100 DOT during that period ($P < 0.01$), 100 DOT had the lowest F:G during that period ($P = 0.02$).

Using the following quadratic equation for carcass-adjusted ADG: $y = -0.00004204\ (\pm 0.0002044)\ \text{DOT}^2 + 0.008339\ (\pm 0.0041733)\ \text{DOT} + 3.763\ (\pm 0.19398)$ and solving for the first-derivative, carcass-adjusted ADG is optimized at 99 DOT. The quadratic equation for carcass adjusted G:F is: $y = -0.00000128\ (\pm 0.000000577)\ \text{DOT}^2 + 0.0002222\ (\pm 0.0001179)\ \text{DOT} + 0.15865\ (\pm 0.0054785)$ and when solved for the first-derivative, G:F was maximized at 87 DOT. This simply means that to get the best gain and conversion, reimplanting between 87 and 99 days from harvest is best. However, small differences were observed anywhere from 80 to 120 days from harvest for the terminal implant, suggesting some flexibility for marketing.

Conclusion

Overall, performance was the greatest when steers spent 100 or 120 days exposed to the terminal implant (Revalor-200). When solving for the first-derivative for both carcass-adjusted ADG and feed efficiency, performance was maximized at 99 or 87 DOT, respectively. The relatively minor differences in performance and carcass characteristics when steers are reimplanted between 80 to 120 d prior to harvest suggests flexibility in reimplanting windows.

Table 3. Effect of DOT (Revalor-200) following initial implant (Revalor-IS) on interim performance of steers fed for 180 d.

	Days on Revalor-200								
	160	120	100	80	40	SEM	F-Test	Linear	Quad.
Day 1–20									
DMI, lb/d	20.3	20.8	20.6	20.4	20.3	0.20	0.47	0.16	0.77
ADG, lb[2]	3.40	3.56	3.91	3.40	3.29	0.25	0.48	0.13	0.32
F:G[1]	5.95	5.81	5.29	5.98	6.17	-	0.56	0.16	0.32
Day 21–61									
DMI, lb/d	24.6	25.1	24.5	24.8	24.3	0.31	0.42	0.99	0.96
ADG, lb	5.27	4.72	4.60	4.89	4.75	0.13	<0.01	0.12	0.09
F:G	4.69	5.32	5.32	5.07	5.13	-	0.01	0.17	0.12
Day 62–81									
DMI, lb/d	27.7	26.7	27.2	27.4	26.3	0.34	0.04	0.92	0.35
ADG, lb	5.24	5.55	5.09	5.04	4.96	0.21	0.34	0.44	0.36
F:G	5.32	4.81	5.37	5.46	5.29	-	0.16	0.43	0.17
Day 82–101									
DMI, lb/d	27.2	27.3	25.2	26.0	26.4	0.37	<0.01	0.35	<0.01
ADG, lb	3.68	4.16	3.93	3.49	3.24	0.22	0.06	0.03	0.95
F:G	7.41	6.58	6.45	7.46	8.20	-	0.02	<0.01	0.23
Day 102–141									
DMI, lb/d	27.8	28.1	27.4	26.7	26.6	0.29	<0.01	0.01	0.12
ADG, lb	3.92	4.42	4.49	4.34	3.94	0.12	<0.01	0.09	<0.01
F:G	7.09	6.33	6.10	6.13	6.71	-	<0.01	0.45	<0.01
Day 142–180									
DMI, lb/d	27.2	27.9	28.2	27.9	26.1	0.38	<0.01	0.14	<0.01
ADG, lb	2.68	2.72	3.19	3.34	3.64	0.18	<0.01	0.10	0.08
F:G	10.10	10.31	8.77	8.26	7.19	-	<0.01	0.03	0.25

[1] Analyzed as G:F.

[2] Calculated from pencil-shrunk (4%) interim BW

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Evaluation of an Algal Biomass as an Ingredient in Cattle Feed

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Summary with implications

*A study was conducted evaluating the effects of feeding condensed algal residue solubles (***CARS***; available in 2019 in Blair, NE area) to finishing cattle for 100 days. Four levels of CARS were evaluated with 5 steers and 5 heifers individually fed per level of inclusion. The diets consisted of 70% dry rolled corn with CARS displacing corn at 0, 2.5, 5, and 7.5% of dry matter. Increasing CARS inclusion resulted in a linear decrease in intake, a quadratic increase in daily gain, and a linear decrease in feed:gain. Calculations showed a linear increase in dietary net energy as CARS increased in the diet. Minimal differences in organ weights, blood chemistry, hematology, and urine were observed. Daily observations and histology results suggest no differences in cattle health due to dietary treatment. Including CARS at 5% of diet dry matter increased gain 4.2% and feed:gain 10.1% relative to a corn based finishing diet.*

Introduction

With more interest in algae derived omega-3 fatty acids for both human and animal feeds, coproducts from the algae industry could result in an alternative feed ingredient for cattle. Condensed algal residue solubles (CARS; Veramaris, Netherlands) is produced from heterotrophic algae as a result of producing omega-3 fatty acids and is a potential source of protein, fiber and fat, which could contribute essential nutrients in cattle diets. The CARS is produced by condensing the residue from algal fermentation of dextrose after the oil has been extracted from the algal cells without organic solvents and has a syrupy consistency. CARS will be produced and available starting in 2019 in the Blair, NE area. Little research has been conducted on this novel feed ingredient; therefore, the objectives of this study were to evaluate the safety of CARS as a cattle feed and performance of cattle being fed increasing inclusion of CARS relative to corn for finishing cattle.

Table 1. Composition of diets containing increasing inclusions of Condensed Algal Residue Solubles (CARS) and individually fed to steers and heifers

	Treatment[1]			
Ingredient, % diet DM	0%	2.5%	5%	7.5%
Dry rolled corn	70.0	67.5	65.0	62.5
Wet distillers grains	15.0	15.0	15.0	15.0
Grass hay	10.0	10.0	10.0	10.0
Algae	—	2.5	5.0	7.5
Supplement[2]	5.0	5.0	5.0	5.0
Fine ground corn	2.28	2.49	2.70	3.12
Limestone	1.69	1.69	1.69	1.69
Tallow	0.125	0.125	0.125	0.125
Urea	0.54	0.405	0.27	—
Salt	0.30	0.225	0.15	—
Trace mineral premix[3]	0.05	0.05	0.05	0.05
Vitamin A-D-E premix[4]	0.015	0.015	0.015	0.015

[1] Differences in dietary treatments were due to CARS inclusion (0, 2.5, 5, or 7.5% of diet DM).

[2] Two supplements were formulated and blended together for the 2.5 CARS and 5 CARS treatments. Supplement provided Rumensin (330 mg/animal daily; Elanco, Greenfield, IN), and Tylan (90 mg/animal daily; Elanco)

[3] Trace mineral premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co.

[4] Vitamin A-D-E premix contained 1500 IU vitamin A, 3000 IU vitamin D, and 3.7 IU vitamin E per g.

Procedure

A trial was conducted using forty crossbred cattle (20 steers, 20 heifers) blocked by initial body weight (BW; 563 ± 31 lb) into 10 blocks. Five days prior to trial initiation, cattle were limit fed at 2% of BW to reduce gut fill variation on a 50% Sweet Bran (Cargill wet milling, Blair, NE) and 50% alfalfa hay diet. Cattle were weighed on 3 consecutive days and the average was used as initial BW. The diets consisted of increasing inclusion of CARS (0, 2.5, 5, and 7.5%) displacing dry rolled corn in the diet (70.0, 67.5, 65.0, and 62.5%), 15% wet distillers grains, 10% grass hay, and 5% supplement (Table 1). All cattle were individually fed at ENREC (near Mead, NE) using the Calan gate system with two pens, one for steers and one for heifers.

Cattle were fed ad-libitum once daily. Feed refusals were collected weekly, weighed and then dried in a 60º C forced air oven for 48 hours to calculate accurate DMI per individual. Interim BW, urine, blood and veterinary observations were obtained on days 0, 33, 61, 90 and harvest day. Urine was analyzed at the UNL Veterinary Diagnostic Center for protein, pH, ketone bodies, bilirubin, urobilinogen glucose, and microscopic examination. Blood samples were sent to Iowa State University Veterinary Pathology Laboratory and analyzed for common hematology and blood

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Table 2. Nutrient composition of Condensed Algal Residue Solubles (CARS)

Item	CARS[1]
Dry matter (DM), %	41.7
%, DM basis	
Crude protein	29.3
Neutral detergent fiber	34.6
Acid detergent fiber	2.3
Calcium	0.16
Phosphorus	0.82
Potassium	1.51
Sulfur	2.54
Sodium	8.52
ppm, DM basis	
Magnesium	0.33
Zinc	43.87
Iron	86.33
Manganese	13.5
Copper	6.00
Molybdenum	0.69

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

Table 3. Performance of steers and heifers individually fed Condensed Algal Residue Solubles (CARS) at increasing inclusions

	Treatment[1]					Contrast		
Item	0	2.5	5	7.5	SEM	Linear	Quadratic	Cubic
Initial BW, lb	562	563	568	560	4.1	0.94	0.27	0.33
Final BW, lb	920^{ab}	944^{a}	941^{a}	891^{bc}	11.7	0.10	< 0.01	0.71
HCW, lb	525^{a}	536^{a}	537^{a}	498^{b}	8.8	0.05	0.01	0.50
DMI, lb/d	19.4^{a}	19.8^{a}	18.1^{b}	16.2^{c}	0.45	< 0.01	0.01	0.32
ADG, lb	2.89^{abc}	3.09^{a}	3.01^{ab}	2.67^{c}	0.088	0.07	< 0.01	0.97
F:G, lb	6.02^{a}	5.78^{a}	5.41^{b}	5.38^{c}	—	< 0.01	0.36	0.30
NE_m, Mcal/lb	4.01^{a}	4.10^{a}	4.37^{b}	4.58^{b}	0.060	< 0.01	0.78	0.21
NE_g, Mcal/lb	2.62^{a}	2.69^{a}	2.93^{b}	3.02^{b}	0.053	< 0.01	0.78	0.21

[1]Differences in dietary treatments were due to CARS inclusion (0, 2.5, 5, or 7.5% of diet DM).

BW = body weight; HCW = hot carcass weight; DMI = dry matter intake; ADG = average daily gain; F:G = feed to gain; NE_m = net energy for maintenance; NE_g = net energy for gain

[abc]Within a row, means without a common superscript differ ($P < 0.05$).

chemistry. Hematology included white blood cell count, red blood cell count, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, red blood cell distribution width, mean platelet volume, platelet count, and neutrophil, lymphocyte, monocyte, eosinophil, basophil, plasma protein, fibrinogen, hematocrit and hemoglobin concentrations. Blood chemistry measures included Na, K, Cl, Ca, P, Mg, blood urea N, creatinine, glucose, total protein, albumin, alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, gamma glutamyl transpeptidase, lactate dehydrogenase, creatine kinase, total bile acids, bicarbonate, and cholesterol. Daily observations of each individual animal were recorded after feeding by trained animal care staff at the research facility.

Two blocks (4 steers, 4 heifers) were harvested each week starting on day 97. Blocks were harvested at a target body weight of 1000 lb. On each harvest day, all cattle were weighed prior to feeding, cattle to be harvested were sorted off and then transported to the UNL Veterinary Diagnostic Center. Remaining cattle were returned to the corresponding pen and fed. At harvest, organs and tissues (brain, spinal cord, spleen, lung, pancreas, skeletal muscle, rumen reticulum, omasum, abomasum, duodenum, jejunum, cecum, colon, kidneys, urinary bladder, pituitary, thyroid, adrenal, liver, gall bladder, heart, mesenteric lymph node, skin, prostate, eye, bone and marrow, marrow smear, ileum, thymus, ovary, mammary gland, and uterus) were isolated, washed, weighed and sampled for histopathology analysis. After full tissue collection and necropsy, all tissues and carcasses were incinerated.

Data were analyzed using the mixed procedure of SAS as a randomized complete block design with treatment, gender, and treatment by gender interaction as main effects. Orthogonal contrasts were used to test for linear, quadratic, and cubic responses due to CARS inclusion.

Results

The nutrient profile of CARS is shown in Table 2. It is a good source of protein (29.3% of DM), but no research has been done to determine the digestibility and rumen degradation of this protein. It also contains fairly high levels of S (2.54% of DM) and Na (8.52% of DM), which may limit intake at very high dietary inclusion.

There were no interactions between sex and treatment ($P \geq 0.25$) for performance data. Sex was significant for all variables ($P \leq 0.04$) with steers having greater DMI, initial BW, ADG, HCW and final BW, compared to heifers. As CARS inclusion in the diet increased, DMI linearly decreased ($P < 0.01$; Table 3). There was a quadratic ($P < 0.01$) response for ADG with the 2.5% and 5% CARS treatments having the greatest numerical values of 3.09 and 3.01 lb/d, respectively. Live final BW responded quadratically ($P < 0.01$) and was greatest for 2.5% and 5% CARS treatments, 944 and 941 lb, respectively. The 7.5% CARS treatment had the lowest DMI and ADG ($P \leq 0.02$); however, this treatment also had the least F:G (5.38; $P < 0.01$). The F:G linearly decreased ($P < 0.01$) with increasing CARS inclusion in the diet. The energy content of the diets, measured as NEm and NEg linearly increased ($P < 0.01$) as CARS inclusion in the diet increased.

For hematology and blood chemistry parameters, nearly all variables were within the prescribed normal range. Both hemoglobin and hematocrit concentrations quadratically decreased ($P = 0.05$) with increasing inclusion of CARS. The red blood cell distribution width linearly increased ($P = 0.02$) from 20.9 to 22% with increasing inclusion of CARS. Blood Cl and alkaline phosphatase concentrations linearly decreased while blood bicarbonate and creatinine concentrations linearly increased with increasing inclusion of CARS. Blood creatine kinase, gamma-glutamyl transpeptidase, and lactate dehydrogenase all had quadratic effects ($P < 0.05$). There were no other significant differences ($P \geq 0.11$) in hematology or blood chemistry measures between treatments. There were no differences among treatments in urine parameters measured ($P \geq 0.17$), except pH which increased quadratically ($P < 0.01$)

with increasing CARS inclusion (range of 8.0 to 8.7).

Weight of the liver and pancreas, as a % of shrunk BW, linearly increased ($P < 0.01$; 21 and 16%, respectively) with increasing inclusion of CARS in the diet. The weight of the thyroid increased quadratically ($P < 0.01$) as CARS inclusion increased. Differences in organ weights due to CARS inclusion were relatively minor and likely due to nutrient load. There were no significant differences in histology results ($P \geq 0.24$) comparing the 0 and 7.5% CARS treatments, suggesting no differences in the health of the cattle. Daily cattle observations and veterinary visual health observations all suggested cattle were healthy and showed no adverse effects of dietary treatment.

Conclusion

The feedstuff CARS demonstrated to be a safe feed ingredient in cattle diets. Feeding CARS to finishing cattle improved F:G as inclusion in the diet increased up to 7.5% of diet DM. Cattle HCW, ADG, and DMI all increased quadratically with increasing inclusion of CARS from 0 to 7.5% of diet DM. No adverse effects of feeding CARS were observed in hematology, blood chemistry, or histopathology analyses. Further research is needed to determine the optimal level of CARS inclusion in a finishing diet and the impact on carcass traits, as well as potential for CARS to be used in growing cattle diets.

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Impact of Shade in Beef Feedyards on Performance, Body Temperature, and Heat Stress Measures

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Summary with Implications

A study using crossbred steers was conducted at a commercial feedyard to determine the effects of pen shades on cattle performance, body temperature, and cattle activity. Two heat events (Event 1 and Event 2) and one cool event were defined for the feeding period. No significant differences were observed for average daily gain, dry matter intake, feed to gain, or carcass characteristics at the end of the trial. During Event 1, cattle in pens with shade had lower panting scores than cattle in open pens. During Event 2, cattle in shade pens had greater dry matter intake, lower panting scores, and lower ear temperature. Throughout the entire feeding period, cattle in open pens had greater ear temperature and panting scores than cattle in shaded pens while movement was not different between treatments. Using shades for feedyard cattle did not impact performance, but did improve some measures of heat stress.

Introduction

Heat stress in beef feedyards has been shown to reduce feed intake, growth, efficiency, and in extreme cases result in death. One of the most commonly used practices for abating heat stress is the use of shades. Using shades in feed yard pens should increase feed intake and daily gain, improve carcass traits, and reduce the risk of death. The objective of this study was to determine the effect of shade on cattle performance, body temperature, and cattle activity.

Table 1. Composition of finishing diets

Ingredient, % DM	First diet (Fed from Start-July 2)	Second diet (Fed from July 3–Finish)
Dry rolled corn	35	41
Modified distillers grains	37	41
Wet Corn Gluten Feed (ADM)	10	10
Corn Silage	12	0
Corn Stalks (5 in grind)	2	3
Liquid Protein/Supplement[1]	4	5
Rumensin-90[2]	29.4 g/ton of DM	36.7 g/ton of DM
Tylan-40[3]	8.9 g/ton of DM	9.7 g/ton of DM

[1] Performance Plus Liquids (Palmer, NE)

[2] Rumensin (Elanco Animal Health; Greenfield, IN)

[3] Tylan (Elanco Animal Health)

Procedure

A study with crossbred steers (n = 1677; initial BW = 820 lb, SD = 104) was conducted at a commercial feedyard in Eastern NE to determine the effects of shade on cattle performance, panting scores, body temperature, and cattle activity. Cattle were received from March 17 to April 21. Upon arrival at the feedyard, cattle were weighed, given Titanium 5 (Elanco Animal Health; Greenfield, IN), injected with Ivermax Plus (Aspen Veterinary Resources; Greeley, Co), poured with Ivermax Pour On (Aspen Veterinary Resources; Greeley, Co), and implanted with Synovex Choice (Zoetis; Parsippany, New Jersey). Cattle were assigned to treatment as they exited the chute by switching a sort gate every third animal. Cattle were fed a common diet during the trial (Table 1). After the corn silage was depleted in the first diet, they were switched to the second diet on July 3. Cattle were re-implanted with Synovex Choice from June 7 to June 27 depending on start date and weight.

The experimental design was a randomized complete block with 2 treatments. Arrival date was used as the blocking effect. Ten pens were assigned randomly to a treatment as either having shade (SHADE) or no shade (OPEN) with 5 pens per treatment. Six of the pens were 200 by 400 feet and 4 of the pens were 135 by 400 feet. Each pen had approximately 420 ft^2/head. The shades in all the shaded pens were the same size, but number of animals per pen varied. Therefore, the larger pens supplied 30 ft^2/head and the smaller pens supplied 45 ft^2/head of shade.

A subset of 20 (4 smaller pens) or 30 (6 larger pens) steers from each pen were selected randomly based on processing order and given a Quantified Ag biometric sensing ear tag (Quantified Ag, Lincoln, NE). The tag recorded movement every hour and ear temperature 5 times every hour. The data were sent to an antenna located at the feed mill. The antenna was connected to the internet and to Quantified Ag's database. Panting scores were recorded by 1 trained technician on the same subset of animals that had the biometric sensing ear tag at least twice every week from June 8 to August 21 between 1300 and 1700 hours. Panting scores were based on a score of 0 to 4.0 in 0.5 increments with a score of 0 = no panting and 4.0 = open mouth with tongue fully extended, excessive drooling, and neck extended.

During the trial, 2 heat events were defined using wind adjusted temperature-humidity index (adjusted THI). The values used for adjusted THI were from a weather station located 1 mile south of the feedyard. The weather station recorded data every 30 minutes. Figure 1 shows the maximum,

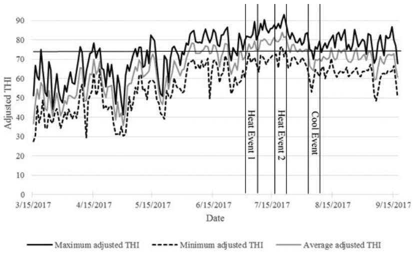

Figure 1. Maximum, minimum, and average adjusted temperature-humidity index (THI) across all days of the trial. The solid line shown at a THI of 74 represents the threshold set by the Livestock Weather Safety Index for heat stress in cattle. Heat Event 1 was from July 3 to July 7, Heat Event 2 from July 18 to July 22, and the Cool Event was from August 3 to August 7.

Table 2. Effect of shade in feedlot pens on performance of steers

	Treatments[1]			
Performance (Carcass Adjusted)	Open	Shade	SEM	*P*-Value
Initial BW, lb	825	824	2.1	0.75
Final Live BW, lb	1516	1521	5	0.47
Adjusted Final BW[2], lb	1472	1478	5	0.42
DMI, lb/d	24.6	24.8	0.15	0.31
ADG, lb/d	3.84	3.88	0.02	0.29
F:G[3]	6.40	6.40	–	0.85
Carcass characteristics				
HCW[4], lb	927	931	3.3	0.46
12th rib fat, in	0.60	0.61	0.02	0.49
Marbling score[5]	478	479	5.1	0.92
LM Area[6], in^2	14.3	14.5	0.1	0.24
Calculated YG[7]	3.42	3.43	0.05	0.92

[1] Treatments consisted of 5 open pens and 5 shaded (30 to 45 ft^2/animal) pens

[2] Adjusted Final body weight (BW) calculated from hot carcass weight (HCW) and a common 63% dressing percent

[3] Feed to Gain (F:G) was calculated and analyzed as Gain to Feed

[4] Hot carcass weight

[5] Marbling score: 300 = slight, 400 = small, 500 = modest, etc.

[6] LM area = longissimus muscle (ribeye) area

[7] Calculated Yield Grade (YG) = 2.50 + (2.5 × 12th rib fat, in)-(0.32 × LM area, in^2) + (0.2 × 2.5% KPH) + (0.0038 × HCW, lb)

minimum, and average adjusted THI throughout the trial. The Livestock Weather Safety Index uses an adjusted THI of 74 as the threshold for heat stress in cattle. The first heat event (Event 1) was from July 3 to July 7 and was the first 5 consecutive days in the feeding period with an average daily adjusted THI greater than 74. During Event 1 the daily maximum temperature averaged 86.7°F, daily minimum temperature averaged 66.6°F, maximum humidity averaged 92%, and maximum wind speed averaged 9.1 miles per hour (MPH) across the 5 days. The second heat event (Event 2) was from July 18 to July 22 and was the 5 consecutive days during the feeding period with the greatest adjusted THI. During Event 2 the daily maximum temperature averaged 90.9°F, daily minimum temperature averaged 72.6°F, maximum humidity averaged 92%, and maximum wind speed averaged 9.7 MPH across the 5 days. A cool event was also defined from August 3 to August 7 and was the first 5 consecutive days following the 2 heat events with an average daily adjusted THI less than 70. During the cool event the daily maximum temperature averaged 73.1°F, daily minimum temperature averaged 55.6°F, maximum humidity averaged 97%, and maximum wind speed averaged 7.2 MPH across the 5 days.

The first block of cattle was shipped on September 8 and the final block was shipped on September 20. Cattle were harvested at Cargill Meat Solutions (Schuyler, NE). Carcass characteristics and cattle performance were analyzed using the MIXED procedure of SAS (SAS Institute Inc. Cary, NC) with pen as the experimental unit. Panting scores and biometric sensing ear tag data were analyzed using the GLIMMIX procedure of SAS as repeated measures with pen as the experimental unit. Biometric sensing ear tag data were analyzed with a treatment by hour interaction sliced by hour (each hour of the day was analyzed together). For example, any recording from 0000 to 0100 hours would be analyzed together and be known as hour 0.

Results

There were no differences in SHADE cattle compared to OPEN cattle for dry matter intake (DMI), average daily gain (ADG), feed to gain (F:G) or carcass characteristics ($P \geq 0.24$; Table 2). Figure 2 shows the ear temperature of the cattle with the biometric sensing ear tag across all days of the trial (April 28 to September 8). Ear temperature had a treatment by hour interaction ($P < 0.01$) with OPEN cattle being significantly hotter than the SHADE cattle from 1300 to 1800 hours ($P \leq 0.05$), but not different during the other hours of the day. Movement was not significantly different between the OPEN and SHADE cattle ($P = 0.38$) across all days (Table 3). Panting scores were greater for OPEN cattle ($P < 0.01$) across all days of the trial.

During Event 1 there were no differences in DMI ($P = 0.32$) or ear temperature ($P = 0.24$) between treatments (Table 3). Panting scores were lower for SHADE cattle compared to OPEN cattle ($P < 0.01$). Event 2 was a more severe heat event compared to Event 1. During Event 2 the SHADE cattle had greater DMI compared to OPEN cattle ($P < 0.01$). Panting scores and ear temperature were lower for SHADE cattle than OPEN cattle ($P < 0.01$).

During both Event 1 and 2, movement had a treatment by hour interaction. During Event 1, SHADE cattle had greater movement than OPEN cattle ($P \leq 0.05$) at 1100 h and from 2000 to 2300 h. During Event 2, OPEN cattle had greater movement than SHADE cattle ($P \leq 0.05$) from 1300 to 1400 h, while SHADE cattle had greater movement than OPEN cattle from 1900 to 2000 h, and 2200 to 2300 h.

During the cool event, SHADE cattle still had slightly greater DMI compared to OPEN ($P < 0.01$; Table 3). Panting scores were the same for both treatments ($P = 0.99$), but very little panting occurred during this period. There were no treatment differences for ear temperature ($P = 0.11$) or movement ($P = 0.76$) during the cool event. The cool event showed that, under

Table 3. Main effect of treatment on dry matter intake (DMI) and heat stress measurements during the heat and cool events

	Treatments			*P*-Value		
Item	Open	Shade	SEM	Trt	Hour	Trt×Hour
Heat event 1 (July 3–July 7)[1]						
DMI, lb/d	26.4	26.6	0.44	0.32	-	-
Panting Score[2]	0.88	0.61	0.06	<0.01	-	-
Ear Temperature, °F[4]	100.6	100.4	0.1	0.24	<0.01	0.50
Heat event 2 (July 18–July 22)[1]						
DMI, lb/d	20.9	22.2	0.44	<0.01	-	-
Panting Score[2]	1.75	1.42	0.07	<0.01	-	-
Ear Temperature,°F[4]	100.8	100.4	0.1	<0.01	<0.01	0.28
Cool Event (August 3–August 7)						
DMI, lb/d	25.7	26.4	0.22	<0.01	-	-
Panting Score[2]	0.00	0.00	0.00	0.99	-	-
Movement[3]	30248	30593	1595	0.76	<0.01	0.96
Ear Temperature, °F[4]	98.1	97.7	0.1	0.11	<0.01	0.99
All days of the trial[1]						
Panting Score	0.74	0.55	0.02	<0.01	-	-
Movement	29032	29827	636	0.38	<0.01	0.99

[1] Movement from Heat Event 1 and Heat Event 2 are not shown in this table due to the treatment by hour interaction. These interactions are shown in Figures 3 and 4. Ear temperature across the entire trial also had a treatment by hour interaction and is shown in Figure 2.

[2] Panting Scores were based on a score of 0 to 4.0 in 0.5 increments

[3] Movement was measured using a biometric sense tag (Quantified Ag, Lincoln, NE) that measured total movement as well as velocity of that movement in a 3-dimensional space (n = 131 SHADE; n = 130 OPEN)

[4] Ear Temperature was measured using a biometric sense tag (Quantified Ag, Lincoln, NE; n = 131 SHADE; n = 130 OPEN)

thermoneutral conditions, SHADE cattle behave the same and have the same body temperature as OPEN cattle.

Conclusion

The use of shades in feedyards can decrease heat stress and minimize potential death loss of cattle on feed. This is evident from the greater DMI, lower panting scores, and lower ear temperature of SHADE cattle compared to OPEN during Event 2. Using shades for feedyard cattle did not impact performance over the entire feeding period, but did improve some measures of heat stress.

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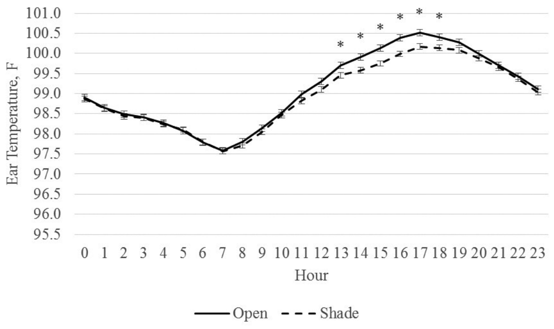

Figure 2. Effect of treatment (SHADE or OPEN) on ear temperature of cattle (n = 131 SHADE; 130 OPEN) during the entire trial. Ear temperature was measured using a biometric sense tag (Quantified Ag, Lincoln, NE). The interaction between treatment and hour was significant ($P < 0.01$). Treatment differences are significant ($P < 0.05$) at time points in the figure denoted with an *.

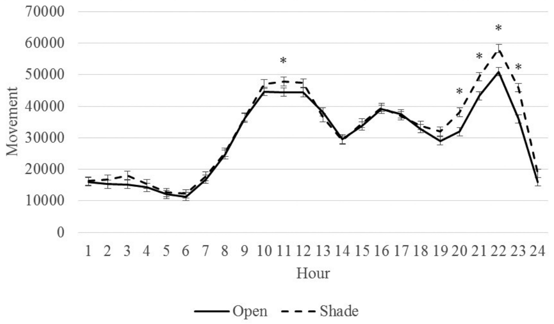

Figure 3. Effect of treatment (SHADE or OPEN) on movement of cattle (n = 131 SHADE; 130 OPEN) during Heat Event 1 (July 3 to July 7). Movement was measured using a biometric sense tag (Quantified Ag, Lincoln, NE) that measured total movement as well as velocity of the movement in a 3-dimensional space. The interaction between treatment and hour was significant ($P < 0.01$). Treatment differences are significant ($P < 0.05$) at time points in the figure denoted with an *.

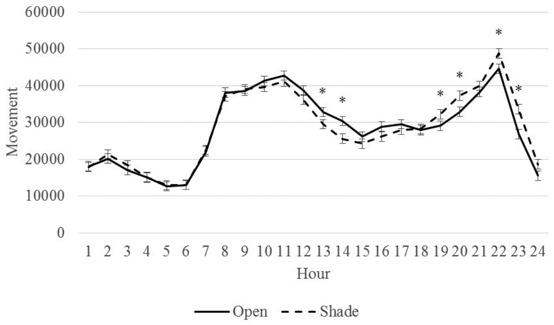

Figure 4. Effect of treatment (SHADE or OPEN) on movement of cattle (n = 131 SHADE; 130 OPEN) during Heat Event 2 (July 18 to July 22). Movement was measured using a biometric sense tag (Quantified Ag, Lincoln, NE) that measured total movement as well as velocity of the movement in a 3-dimensional space. The interaction between treatment and hour was significant ($P < 0.01$). Treatment differences are significant ($P < 0.05$) at time points in the figure denoted with an *.

Evaluation of Fractionated Distillers Grains (High Protein and Bran Plus Solubles) on Performance and Carcass Characteristics in Finishing Diets

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F. Henry Hilscher
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Ryan A. Mass

Summary with Implications

A finishing study evaluated the effect of feeding a new, high protein distillers grains along with corn bran plus condensed distillers solubles compared to traditional wet distillers grains, traditional dry distillers grains and a corn-based control. Each byproduct replaced corn at 40% of the diet dry-matter. Intake was not affected by treatment; however gain and carcass weight were greater and feed conversion improved for high protein distillers and corn bran plus solubles than either type of traditional distillers grains or corn. Based on feed efficiency, the feeding values of high protein distillers grains and corn bran plus solubles are 121% and 125% that of corn, respectively. These new byproducts appear to be viable options for producers to utilize in finishing diets.

Introduction

Traditional wet distillers grains have approximately 130% the energy value of corn (*2011 Nebraska Beef Cattle Report*, p. 40). The positive performance observed with distillers grains has largely been attributed to the protein fraction (*2016 Nebraska Beef Cattle Report*, pp. 124–127). Recent technological advancements (ICM Inc., Colwich, KS) have allowed ethanol plants to fractionate products during the ethanol production process. Corn fiber (also referred to as corn bran) removal further concentrates other components of distillers grains—most notably the protein. This isolation process allows for greater ethanol production, but creates a distillers product with differing composition than what is currently produced. Furthermore, some of the isolated bran can be combined with condensed distillers solubles (CDS) to create another new feed byproduct. How the new ethanol byproducts impact animal performance has not been evaluated for this process. Therefore, the objective of this study was to evaluate the effect of feeding high protein distillers grains, as well as corn bran plus solubles, on animal performance and carcass characteristics in finishing cattle.

Table 1. Nutrient composition of high protein dry distillers grains (HiPro DDGS), corn bran plus solubles (Bran + Solubles), traditional wet distillers grains plus solubles (WDGS), and traditional dry distillers grains plus solubles (DDGS) fed in beef finishing diets

Nutrient[1]	HiPro DDGS	Bran + Solubles	WDGS	DDGS
DM, %	91.8	40.7	32.8	91.4
CP, %	36.0	33.5	30.1	32.5
NDF, %	32.0	32.3	30.2	31.6
Fat, %	9.4	9.8	11.6	6.2

[1] Nutrients expressed on a dry-matter basis

Procedure

A 190-day finishing study was conducted at the University of Nebraska feedlot near Mead, NE utilizing 300 cross-bred calf-fed steers (initial BW = 621 ± 21 lb) to evaluate the effect of feeding a new distillers grains that have undergone a pre-fermentation fiber separation process. Steers were limit fed a common diet of 50% Sweet Bran (Cargill, Blair, NE) and 50% alfalfa hay at two percent of BW for 5 days prior to initiation of the trial to equalize gut fill. Animals were weighed on two consecutive days (d 0 and d 1) to establish average initial BW. Steers were blocked by initial BW into one of three blocks, stratified within block and assigned randomly to pen. Pens were assigned randomly to one of five treatments with 10 steers/pen and 6 pens/treatment. Treatments were arranged in a randomized block design, and included high protein dry distillers grains (HIPRO), corn bran plus solubles (BRAN+SOL), traditional dry distillers grains (DDGS), traditional wet distillers grains (WDGS), and a corn-based control (CON). High protein distillers grains and Bran + Solubles were produced from the same process and were sourced from the same ethanol plant (Corn Plus, Winnebago, MN). Traditional dry and wet distillers were sourced from E Energy (Adams, NE) and KAAPA Ethanol (Ravenna, NE), respectively. The nutrient composition of each byproduct is provided in Table 1. Byproducts replaced a 50:50 blend of high-moisture and dry-rolled corn at 40% diet (DM; Table 2). All diets contained 15% corn silage and 5% supplement. Supplements were formulated to provide 30 g/ton Rumensin® (Elanco Animal Health, Greenfield, IN) and 8.8 g/ton Tylan® (Elanco Animal Health, Greenfield, IN). Soypass® (LignoTech USA, INc., Rothschild, WI) was phase fed in the control diet to meet metabolizable protein requirements.

Steers were implanted with Revalor XS® (Merck Animal Health, DeSoto, KS) on day one, and were harvested at a commercial packing plant (Greater Omaha, Omaha, NE) where HCW and liver scores were collected on the day of slaughter. Ribeye area, marbling score, and 12th rib fat thickness were recorded after a 48 h chill. Final BW, ADG, and F:G were adjusted by HCW using a 63% dress.

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) as a randomized block design. Pen was used as the experimental unit while block was analyzed as a fixed effect.

Table 2. Composition of dry-rolled and high-moisture corn finishing diets with dry distillers grains plus solubles (DDGS), high protein dry distillers grains (HIPRO), wet distillers grains plus solubles (WDGS), or corn bran plus solubles (BRAN+SOL)

	Treatment[1]				
	CON[2]	DDGS	HIPRO	WDGS	BRAN+SOL
Ingredients					
High-moisture Corn	39.25	20.50	20.50	20.50	20.50
Dry-rolled Corn	39.25	20.50	20.50	20.50	20.50
Corn Silage	15.00	15.00	15.00	15.00	15.00
HiPro DDG	-	-	40.00	-	-
DDGS		40.00	-	-	-
WDGS	-	-	-	40.00	-
Bran + Solubles	-	-	-	-	40.00
Supplement					
Fine Ground Corn	-	1.8875	1.8875	1.8875	1.8875
Limestone	1.6600	1.6200	1.6200	1.6200	1.6200
Tallow	0.1625	0.1000	0.1000	0.1000	0.1000
Urea	1.2900	-	-	-	-
Soybean Meal	3.0000	-	-	-	-
Salt	0.3000	0.3000	0.3000	0.3000	0.3000
Beef Trace Min.	0.0500	0.0500	0.0500	0.0500	0.0500
Vit. ADE	0.0150	0.0150	0.0150	0.0150	0.0150
Rumensin-90	0.0165	0.0165	0.0165	0.0165	0.0165
Tylan-40	0.0110	0.0110	0.0110	0.0110	0.0110

[1] CON: Corn-based control diet with 50:50 blend of high-moisture and dry-rolled corn; DDGS: Dry distillers grains plus solubles; HiPRO: High Protein distillers grains; WDGS: Wet distillers grains plus solubles; BRAN+SOL: Corn bran plus condensed distillers solubles

[2] Soy-Pass was phase fed to meet MP requirements

Table 3. Performance and carcass characteristics for calf-fed steers fed a corn-based control (CON), traditional dry distillers grains plus solubles (DDGS), high protein distillers grains (HIPRO), wet distillers grains plus solubles (WDGS), or corn bran plus solubes (BRAN+SOL) in finishing diets

	Treatment						
	CON	DDGS	HIPRO	WDGS	BRAN+SOL	SEM	*P*-Value
Performance							
Initial BW, lb	604	604	602	604	605	1.8	0.70
Final BW, lb	1316[b]	1347[ab]	1365[a]	1314[b]	1385[a]	17.3	0.03
DMI, lb/d	21.6	21.4	21.2	21.0	21.3	0.28	0.62
ADG, lb	3.76[b]	3.93[ab]	4.03[a]	3.75[b]	4.11[a]	0.089	0.02
F:G	5.71[c]	5.46[bc]	5.26[ab]	5.59[c]	5.18[a]	-	0.02
Carcass Characteristics							
HCW, lb	829[b]	849[ab]	860[a]	828[b]	872[a]	10.9	0.03
LM Area, in^2	13.2	13.5	13.3	13.3	13.6	0.26	0.84
Marbling[1]	463	480	461	453	454	14.5	0.69
Fat Depth, in		0.51	0.50	0.48	0.50	0.022	0.92
Calc YG[2]		3.2	3.3	3.1	3.2	0.11	0.86

[abc] Values within rows with unique superscripts are different ($P < 0.10$)

[1] 400 = Small^0, 500 = Modest^0

[2] Calculated as 2.5 + (2.5 x 12th rib fat, in) + (0.2 x 2.5 (KPH, %)) + (.0038 x HCW, lb)–(0.32 x REA, in^2)

Feeding values were calculated using the following equation: $\{((((G:F_{TRT–} G:F_{CON})/ G:F_{CON}) / \text{byproduct inclusion, \%}) + 1\} * 100$. Feed efficiency of treatment is denoted as $G:F_{TRT}$, and $G:F_{CON}$ represents the feed efficiency of the control treatment.

Results

Intakes were not affected by treatment ($P = 0.62$; Table 3). Average daily gain (ADG) was impacted by dietary treatment ($P = 0.02$) with steers fed HIPRO or BRAN+SOL having the greatest ADG. Steers fed CON or WDGS had similar ($P = 0.96$) gains to one another, but were lowest among all treatments. Dry distillers grains steers were intermediate, but not different ($P > 0.14$) from any other treatments. Similar intakes and improved ADG resulted in the HIPRO and BRAN+SOL treatments having improved ($P < 0.05$) F:G compared to CON and WDGS. The DDGS treatment was again intermediate and not different ($P > 0.20$) than HIPRO, CON, or WDGS. Feeding BRAN+SOL tended ($P = 0.09$) to improve F:G over DDGS. Hot carcass weight and final BW followed a similar trend to ADG. The HIPRO and BRAN+SOL cattle had the greatest HCW, but were not different ($P > 0.41$) from each other. Steers fed CON or WDGS had the lightest weights, while DDGS again was intermediate. No other performance or carcass characteristics were affected by dietary treatment ($P \geq 0.62$).

Feeding HIPRO resulted in a seven percent improvement in feed efficiency over CON while feeding BRAN+SOL resulted in a nine percent improvement. Based on the feed efficiencies of these new byproducts, the feeding value of high protein distillers grains was 121% of corn and the isolated bran plus solubles is 126% that of corn.

Conclusion

Feeding both high protein distillers grains and isolated corn bran plus solubles to finishing cattle improved ADG and F:G over a corn-based control diet. The fiber isolation process separates bran, which concentrates crude protein in the resulting distillers grains product. These two new ethanol byproducts appear to be viable feeds for finishing cattle. With feeding values of 121% and 126% respectively, high protein distillers grains and corn bran plus solubles fit well will values for traditional distillers grains.

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Evaluation of Corn Bran Plus Solubles on Performance and Carcass Characteristics in Finishing Diets

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Summary with Implications

A finishing study was conducted to determine the effect of feeding corn bran plus solubles, a new feed resulting from a pre-fermentation fiber removal process, compared to wet distillers grains plus solubles at two levels of inclusion (20% and 40% of diet DM). Intake increased with inclusion of byproduct, and steers fed 20% wet distillers had the greatest intakes numerically. Byproduct inclusion, regardless of type, increased daily gain over the corn-based control. Feed conversions were improved with increased inclusion of both Bran + Solubles and wet distillers, and both were superior to the control. Increased inclusion of both byproducts resulted in a linear increase in carcass weight. Feeding Bran+Solubles resulted in performance and carcass characteristics similar to wet distillers at both 20% and 40% inclusion.

Table 1. Composition of dry-rolled and high-moisture corn finishing diets with corn bran plus solubles (BRAN+SOL) or wet distillers grains (WDG) at 20 or 40% DM inclusion

	Treatment[1]				
	CON	20BRAN+SOL	40BRAN+SOL	20WDG	40WDG
Ingredients					
High Moisture Corn	44	34	24	34	24
Dry Rolled Corn	44	34	24	34	24
Grass Hay	7	7	7	7	7
Wet Distillers Grains + Solubles	-	-	-	20	40
Bran + Solubles	-	20	40	-	-
Supplement					
Fine Ground Corn	1.553	2.153	2.753	2.153	2.753
Limestone	1.730	1.730	1.730	1.730	1.730
Tallow	0.125	0.125	0.125	0.125	0.125
Urea	1.200	0.600	-	0.600	-
Salt	0.300	0.300	0.300	0.300	0.300
Beef Tr. Min.	0.050	0.050	0.050	0.050	0.050
Vit. ADE	0.015	0.015	0.015	0.015	0.015
Rumensin-90	0.017	0.017	0.017	0.017	0.017
Tylan-40	0.011	0.011	0.011	0.011	0.011
Nutrient Composition					
DM	77.69	69.80	61.87	69.61	61.48
CP	11.34	12.67	14.00	13.81	16.29

[1] CON: Corn-based control diet with 50:50 blend of high-moisture and dry-rolled corn; 20BRAN+SOL: Bran + Solubles fed at 20% diet DM; 40BRAN+SOL: Bran + Solubles fed at 40% diet DM; 20WDG: Wet distillers grains fed at 20% diet DM; 40WDG: Wet distillers grains fed at 40% diet DM

Introduction

Recent changes to the ethanol production process have allowed for the production of cellulosic ethanol from fiber separation technologies. Fiber can be separated pre-fermentation to allow for increased starch utilization, and an increase in ethanol yields. Currently, the removed fiber component may be utilized in combination with condensed distillers solubles (CDS) to make a feed termed Bran + Solubles. Feeding Bran + Solubles at 40% of the diet resulted in greater average daily gain (ADG; $P = 0.02$) and improved feed to gain (F:G; $P = 0.02$) than feeding a high-moisture corn (HMC) and dry-rolled corn (DRC) blend, or distillers grains at 40% of diet DM (*2019 Nebraska Beef Cattle Report*, pp. 94–96). An understanding of how inclusion level effects performance when this new byproduct is utilized is necessary. Thus, our objective was to evaluate the feeding value of Bran + Solubles and compare that to wet distillers grains plus solubles (WDGS) fed at differing inclusions.

Procedure

A 120-day finishing study was conducted at the University of Nebraska feedlot near Mead, NE utilizing 300 cross-bred yearling steers (initial BW = 912 ± 80 lb) to evaluate the effect of feeding corn bran plus solubles in comparison to wet distillers grains. Steers were limit fed a common diet 5 days prior to initiation of the trial to equalize gut fill. Steers were weighed on two consecutive days (d 0 and d 1) to establish average initial BW. Steers were blocked by initial BW into one of four blocks, stratified within block and assigned randomly to pen. Pens were randomly assigned to one of five treatments with 10 steers/pen and 6 pens/treatment. Treatments were arranged in a 2 × 2 + 1 factorial with byproduct type (WDGS or Bran + Solubles) and byproduct inclusion level (20% or 40% diet (DM)) being the factors, plus a corn-based control (CON; Table 1). To produce the new feed byproduct, a counter-current washing system is utilized to separate the bran from starch. The starch is then further processed

Table 2. Performance and carcass characteristics for yearling steers fed a corn-based control (CON), corn bran plus solubles (BRAN+SOL) or wet distillers grains (WDG) at 20 or 40% DM inclusion in finishing diets

	Treatment							*P*-values			
								BRAN+SOL		WDG	
	CON	20BRAN+ SOL	40BRAN+ SOL	20WDG	40WDG	SEM	F-test	Lin.	Quad	Lin.	Quad
Performance											
Initial BW, lb	915	914	913	917	914	1.4	0.34	0.39	0.92	0.93	0.14
Final BW, lb	1362^{b}	1420^{a}	1428^{a}	1428^{a}	1434^{a}	12.1	<0.01	<0.01	0.10	<0.01	0.05
DMI, lb/d	27.0^{c}	29.0^{ab}	29.4^{ab}	29.8^{a}	28.4^{b}	0.36	<0.01	<0.01	0.08	0.01	<0.01
ADG, lb	3.73^{b}	4.22^{a}	4.29^{a}	4.26^{a}	4.33^{a}	0.100	<0.01	<0.01	0.10	<0.01	0.06
F:G	7.19^{b}	6.85^{ab}	6.85^{ab}	6.94^{b}	6.54^{a}	-	0.07	0.10	0.42	<0.01	0.62
Carcass characteristics											
HCW, lb	862^{b}	895^{a}	907^{a}	903^{a}	907^{a}	7.9	<0.01	<0.01	0.27	<0.01	0.06
Marbling [1]	507^{ab}	524^{ab}	499^{b}	489^{b}	535^{a}	12.4	0.09	0.64	0.17	0.12	0.04
Fat depth, in	0.50^{b}	0.55^{ab}	0.55^{ab}	0.59^{a}	0.58^{a}	0.017	0.07	0.29	0.62	0.03	0.06
REA, in^{2}	12.9	12.7	13.1	12.6	12.9	0.19	0.36	0.88	0.09	0.77	0.27
Calc YG [2]	3.27^{c}	3.58^{ab}	3.51^{b}	3.73^{a}	3.64^{ab}	0.078	<0.01	0.04	0.06	<0.01	<0.01

Values within rows with unique superscripts are different ($P \leq 0.05$)

[1] 300 = Slight, 400 = Small, 500 = Modest

[2] Calculated as 2.5 + (2.5 x 12th rib fat, in) + (0.2 x 2.5(KPH, %))–(0.32 x REA, in^{2}) + (0.0038 x HCW, lb)

to produce ethanol. Bran is combined with condensed distillers solubles (CDS) in approximately a 50:50 blend to make Bran + Solubles (ICM Inc., Colwich, KS). Bran + Solubles is approximately 40% DM, 31% CP, and 32% NDF. Byproducts replaced a 50:50 blend of high-moisture and dry-rolled corn. All diets contained 7% grass hay and 5% supplement. Supplements were formulated to provide 30 g/ton Rumensin® (Elanco Animal Health, Greenfield, IN) and 8.8 g/ton Tylan® (Elanco Animal Health, Greenfield, IN).

Steers were implanted with Component TE-200® (Elanco Animal Health, Greenfield, IN) on day 22, and were harvested at a commercial packing plant (Greater Omaha, Omaha, NE) where HCW and liver scores were collected on the day of slaughter. Ribeye area, marbling score, and 12th rib fat thickness were recorded after a 48 h chill. Final BW, ADG, and F:G were adjusted based on HCW using a 63% dress.

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) as a randomized block design. Pen was the experimental unit while block was analyzed as a fixed effect. Orthogonal contrasts were used to analyze linear and quadratic effects of inclusion of each byproduct. Feeding values were calculated based on feed efficiency (G:F) using the following equation: $\{(((G{:}F_{TRT-}G{:}F_{CON})/G{:}F_{CON})$ / byproduct inclusion, %) + 1} * 100. Feed efficiency of treatment is denoted as $G{:}F_{TRT}$, and $G{:}F_{CON}$ represents the feed efficiency of the control treatment.

Results

Dry matter intake quadratically ($P < 0.01$) increased with greater inclusion of WDGS, and tended ($P = 0.08$) to increase quadratically when BRAN+SOL inclusion was increased (Table 2). Steers fed 20% WDGS numerically had the greatest DMI, but were not statistically different ($P > 0.15$) than steers fed either inclusion of BRAN+SOL. Inclusion of both WDGS and BRAN+SOL linearly increased ADG ($P < 0.01$), and both byproducts resulted in better gains than corn alone. A linear ($P < 0.01$) improvement in F:G was observed with increasing levels of WDGS while a tendency ($P = 0.10$) occurred with increasing levels of BRAN+SOL. Feed conversion was numerically best when feeding 40% WDGS, but was not statistically different ($P > 0.13$) than feeding either 20% or 40% BRAN+SOL.

Carcass weight linearly ($P < 0.01$) increased with inclusion of BRAN+SOL and tended ($P \leq 0.06$) to increase in a quadratic fashion with inclusion of WDGS. Marbling score was numerically greatest with the 40% WDGS treatment, but was not different ($P > 0.11$) than the control or 20% BRAN+SOL treatments. Byproduct-fed cattle tended to ($P = 0.09$) have more backfat than CON cattle although CON steers were not statistically different ($P > 0.24$) than either of the BRAN+SOL treatments. Calculated YG was greatest for the 20% WDGS treatment, but not significantly different ($P > 0.18$) than 40% WDGS or 20% BRAN+SOL treatments. Control cattle had the lowest calculated YG ($P < 0.04$) of all treatments and 40% BRAN+SOL cattle were intermediate. Ribeye area was not affected by dietary treatment.

Feeding BRAN+SOL and WDGS resulted in similar effects to one another for performance and carcass characteristics. Based on feed conversion, BRAN+SOL has a feeding value of 125% and 113% that of corn when fed at 20% and 40% of diet (DM), respectively. In this study, WDGS had a feeding value of 118% and 125% that of corn when fed at 20% and 40% of the diet (DM), respectively.

Conclusion

Feeding both BRAN+SOL and WDGS to finishing cattle improved ADG and F:G over a corn-based control diet. Byproduct inclusion tended to increase fat depth as well as calculated YG over the corn-fed cattle as well. Feeding BRAN+SOL appears to be similar to WDGS for finishing cattle with feeding values of 113 to 125% of corn but varies with inclusion.

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Evaluation of the Energy Value and Nutrient Digestibility of Distillers Grains That Have Undergone a Fiber Separation Process in Finishing Diets

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Summary with Implications

A digestion study was conducted to determine the effects of feeding a new, high protein distillers grains and corn bran plus solubles on nutrient digestibility. Treatments included a corn-based control, high protein distillers at both 20% and 40%, corn bran plus solubles, traditional wet distillers grains and traditional dry distillers grains all at 40% of diet DM. Feeding high protein distillers grains or corn bran plus solubles resulted in decreased digestibility compared to corn or traditional wet and dry distillers grains, but increased energy intake. Traditional wet and dry distillers grains also resulted in decreased digestibilities while energy intake was increased. Volatile fatty acid profiles and pH parameters were not different across treatments. Overall, nutrient digestibility for high protein distillers grains and corn bran plus solubles is similar to traditional wet or dry distillers grains.

Introduction

Recent technological advancements have allowed ethanol plants to fractionate products during the ethanol production process. Corn fiber (also referred to as corn bran) removal further concentrates other components of distillers grains—most notably the protein. This isolation process allows for greater ethanol production, but creates a distillers product with differing composition than what is currently produced. Furthermore, some of the isolated bran can be combined with condensed distillers solubles (CDS) to create another new byproduct. While the protein component of DGS had a similar feeding value to DGS when included at 40% (*2016 Nebraska Beef Cattle Report*, pp. 132–134), an understanding of how the new ethanol byproducts impact nutrient digestibility has not been established (*2019 Nebraska Beef Cattle Report*, pp. 88–90). Therefore, the objective of this study was to evaluate the effect of feeding high protein distillers grains, as well as corn bran plus solubles, on nutrient digestibility in finishing cattle.

Procedure

A 126-d metabolism study was conducted utilizing six ruminally fistulated crossbred yearling steers (BW = 1165 lb ± 69 lb). The experiment was arranged in a 6 x 6 Latin square with six steers and six periods. Steers were assigned randomly to one of six treatments with each steer assigned to each treatment once throughout the study. Treatments included a corn-based control, 20% high protein distillers grains (HIPRO 20), 20% high protein distillers grains (HIPRO 40), 40% corn bran plus solubles (BRAN+SOL), traditional wet distillers grains plus solubles (WDGS), and 40% traditional dry distillers grains plus solubles (DDGS). All diets contained 15% corn silage and supplement. Byproducts replaced a 50:50 blend of high-moisture and dry-rolled corn. The supplement was formulated to provide 90 mg/steer/day of Tylan-90® (Elanco Animal Health, Greenfield, IN) and 30 g/ton of Rumensin-90® (Elanco Animal Health, Greenfield, IN; Table 1).

Steers were housed in individual concrete slatted pens and allowed *ad libitum* access to feed and water. They were fed once daily at 800 and feed refusals were removed and weighed prior to feeding. Ingredient samples were taken on days 17 and 19 of each period. Samples were composited by period, lyophilized, ground through a 1-mm screen on a Willey Mill, and analyzed for dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), fat, crude protein (CP), and gross energy. Energy was calculated using bomb calorimetry and used to calculate nutrient composition of each dietary treatment (Table 1).

Each period was 21 days, and consisted of a 16 day adaptation phase with 5 days of collection. Titanium dioxide, an indigestible marker, was dosed intraruminally twice daily at 800 and 1600 h each day of the experiment to provide a total of 10 g/d for use as an estimate of total fecal output. Fecal grab samples were collected four times daily at 700, 1100, 1500, and 1900 h on days 17–20. Fecal samples were composited by day, then by period. Samples were lyophilized, ground through a 1-mm screen on a Wiley Mill, and analyzed for DM, OM, NDF, and energy for calculation of digestible energy and titanium dioxide.

Submersible wireless pH probes were inserted in the rumen on day 14, and ruminal pH was analyzed from d 17–20. Ruminal pH measurements included average pH, minimum and maximum pH, and magnitude of pH change.

Rumen in situ bags were used to estimate NDF digestibility at 16 and 24 hours of incubation using 1.25 g of dry corn bran. Following incubation, samples were washed and immediately frozen. Bags were analyzed for NDF using the ANKOM system. After being run through the NDF procedure, bags were dried in a 140°F forced-air oven for 16 hours. Weights from the dried bags were used to calculate NDF digestibility. Upon removal of the in situ bags, rumen contents of each steer were mixed and a portion was removed and immediately frozen. This sample was then utilized to determine dry matter of whole rumen contents.

Samples of rumen fluid were collected on day 20 at 700, 1100 and 1400 h and immediately frozen. These samples were later analyzed for volatile fatty acid (VFA) concentration changes over time following feeding.

Digestibility and intake were analyzed using the MIXED procedure of SAS (SAS

Table 1. **Composition of dry-rolled and high-moisture corn finishing diets with high protein distillers grains (HIPRO20 & HIPRO40), corn bran plus solubles (BRAN+SOL), traditional dry distillers grains (DDGS), and traditional wet distillers grains (WDGS)**

	Treatment[1]					
	CON*	HIPRO20	HIPRO40	BRAN+SOL	DDGS	WDGS
Ingredient						
DRC	39.3	30.5	20.5	20.5	20.5	20.5
HMC	39.3	30.5	20.5	20.5	20.5	20.5
Corn Silage	15.0	15.0	15.0	15.0	15.0	15.0
HiPro DDGS	-	20.0	40.0	-	-	-
Bran + Solubles	-	-	-	40.0	-	-
DDGS	-	-	-	-	40.0	-
WDGS	-	-	-	-	-	40.0
Supplement						
FGC	-	1.8875	1.8875	1.8875	1.8875	1.8875
Limestone	1.66	1.62	1.62	1.62	1.62	1.62
Tallow	0.1625	0.10	0.10	0.10	0.10	0.10
Urea	1.29	-	-	-	-	-
SBM	3.00	-	-	-	-	-
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Beef Trace Min.	0.05	0.05	0.05	0.05	0.05	0.05
Vit. ADE	0.015	0.015	0.015	0.015	0.015	0.015
Rumensin-90	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165
Tylan-40	0.011	0.011	0.011	0.011	0.011	0.011
Nutrient Composition, % DM						
DM	63.7	66.0	68.8	50.0	68.7	44.7
NDF	13.9	18.4	22.9	23.0	22.7	22.2
CP	13.4	14.2	19.6	18.6	17.3	18.2
Fat	3.9	5.0	6.1	6.2	4.8	7.0

*Soypass was phase fed to meet MP requirements

[1] Treatments included CON-control; HIPRO20–20% high protein distillers grains; HIPRO40–40% high protein distillers grains; BRAN+SOL-40% corn bran plus solubles; DDGS-40% traditional dry distillers grains; WDGS-40% traditional wet distillers grains

Institute, Inc. Cary, NC). Treatment and period were treated as fixed effects while steer within period was a random effect. Ruminal pH data were summarized by hour and analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc. Cary, NC). P-values ≤ 0.10 were considered significant. If significant, treatments were separated and compared using a t-test.

Results

No treatment differences were observed for dry matter intake ($P = 0.55$; Table 2). However, total tract dry matter digestibility (TTDMD) was decreased ($P < 0.10$) with inclusion of byproduct, regardless of type. When high protein distillers grains were included at 20% diet (DM) TTDMD was intermediate, but not different ($P > 0.16$) than CON and all other byproduct treatments except for HIPRO40. Results for total tract organic matter digestibility (TTOMD) followed the same trend as TTDMD.

Treatment affected NDF intake ($P < 0.01$) with steers fed BRAN+SOL and WDGS having the greatest intake and CON having the least ($P < 0.01$). Steers fed DDGS were intermediate, but not different from ($P > 0.13$) BRAN+SOL, WDGS, or HIPRO20. Total tract NDF digestibility (TTNDFD) was numerically greatest for BRAN+SOL at 61.57%, but was not statistically different ($P > 0.14$) from all other treatments excluding DDGS ($P < 0.01$). The lowest TTNDFD was observed for the DDGS treatment. In situ NDFD was not affected by treatment ($P = 0.89$). Acid detergent fiber intake and digestibility were also impacted by treatment. Intake was greatest for HIPRO40, BRAN+SOL and WDGS. The control treatment resulted in the lowest ADF intake ($P < 0.01$), and HIPRO20 and DDGS were intermediate to all treatments, but not different ($P = 0.32$) from one another. Total tract ADF digestibility (TTADFD) was numerically greatest with the BRAN+SOL treatment; however, inclusion of all byproduct treatments except DDGS ($P = 0.69$) resulted in greater TTADFD than CON ($P < 0.03$).

Digestible energy (DE) intake, expressed as Mcal/d, was not affected by treatment ($P = 0.13$), but tended to be greater for the treatments with 40% byproduct. When expressed as Mcal/lb, dietary treatment was significant ($P < 0,01$). Greatest DE intakes were observed in the HIPRO40, BRAN+SOL, DDGS, and WDGS treatments. Lesser inclusion of high protein distillers (HIPRO20) resulted in the lowest DE intake ($P < 0.09$) while CON was intermediate.

No treatment effects were observed for average pH, maximum pH, or pH magnitude of change ($P > 0.73$; Table 3). Minimum ruminal pH was lowest for the HIPRO20 treatment at 4.85, although this was not significantly different ($P > 0.18$) from CON, BRAN+SOL, DDGS or WDGS. Feeding HIPRO40 resulted in a minimum pH of 5.15; numerically greatest of all treatments.

Treatment did not affect total VFA concentration ($P = 0.75$), proportion of any of the measured VFAs ($P > 0.44$), or Acetate:-Propionate ratio.

Conclusion

Feeding high protein distillers grains and corn bran plus solubles resulted in decreased dry matter and organic matter digestibility. However, energy intake was greater when byproducts were included at 40% of diet (DM). These results agree with previous research on traditional distillers grains products. Though digestibility is lower, the increased energy supply contributes to the increase in performance observed in other experiments where these byproducts were fed. This indicates that digestibility of components not measured (i.e. nitrogen and fate) might be greater for the byproduct

Table 2. Effect of feeding high protein distillers grains or corn bran plus solubles on dry matter, organic matter, NDF and ADF digestibility, energy intake, and in situ NDF digestibility

	Treatment[1]							
	CON	HIPRO20	HIPRO40	BRAN+SOL	DDGS	WDGS	SEM	P-Value
DM								
Intake, lb/d	26.0	26.6	24.19	25.7	24.1	25.1	1.43	0.55
Digestibility,%	79.1^{a}	76.1^{ab}	72.0^{c}	74.5^{bc}	73.1^{bc}	74.0^{bc}	1.55	0.04
OM								
Intake, lb/d	25.1	25.6	23.1	24.5	22.9	23.8	1.36	0.42
Digestibility,%	81.0^{a}	78.0^{ab}	74.6^{b}	77.4^{b}	76.0^{b}	76.8^{b}	1.49	0.06
NDF								
Intake, lb/d	3.6^{d}	4.9^{c}	5.5^{ab}	5.9^{a}	5.5^{abc}	5.6^{a}	0.31	<0.01
Digestibility,%	57.6^{a}	54.0^{ab}	54.0^{ab}	61.6^{a}	45.5^{b}	59.0^{a}	3.58	0.07
ADF								
Intake, lb/d	1.7^{c}	2.8^{b}	3.5^{a}	3.6^{a}	2.6^{b}	3.4^{a}	0.18	<0.01
Digestibility,%	42.0^{b}	58.4^{a}	62.4^{a}	66.9^{a}	44.8^{b}	63.2^{a}	6.86	<0.01
Digestible enegy intake								
Mcal/d	36.81	35.99	39.30	43.23	40.04	42.13	2.360	0.13
Mcal/lb[2]	1.42^{b}	1.36^{c}	1.64^{a}	1.67^{a}	1.68^{a}	1.67^{a}	0.028	<0.01
In situ NDFD, %	49.4	49.5	49.2	49.0	47.5	49.0	0.14	0.89

[a-d] Values within rows with differing superscripts are different ($P < 0.10$)

[1] Treatments included CON-control; HIPRO20–20% high protein distillers grains; HIPRO40–40% high protein distillers grains; BRAN+SOL-40% corn bran plus solubles; DDGS-40% traditional dry distillers grains; WDGS-40% traditional wet distillers grains

[2] Mcal of Digestible Energy per lb of dry feed consumed

Table 3. Effect of feeding high protein distillers grains or corn bran plus solubles on ruminal pH and VFA production

	Treatment[1]							
	CON	HIPRO20	HIPRO40	BRAN+SOL	DDGS	WDGS	SEM	P-Value
pH								
Average pH	5.40	5.36	5.75	5.47	5.53	5.45	0.501	0.73
Maximum pH	6.08	6.35	6.51	6.21	6.23	6.31	0.298	0.90
Minimum pH	4.89^{b}	4.85^{b}	5.15^{a}	4.99^{ab}	5.04^{ab}	4.91^{b}	0.087	0.08
pH Magnitude	1.18	1.49	1.36	1.22	1.19	1.40	0.243	0.83
VFA Proportion, %[2]								
Acetate, %[3]	51.5	48.3	53.1	51.7	49.7	54.2	3.98	0.72
Propionate, %	34.4	37.9	29.4	30.0	34.1	29.1	5.41	0.46
Butyrate, %	10.8	9.1	12.1	14.0	10.9	11.8	2.14	0.60
Total VFA, mM	120.6	112.1	106.9	112.7	109.9	101.2	8.95	0.75
A:P ratio[4]	1.91	1.97	2.22	1.88	1.82	2.04	0.328	0.96

[a-b] Values within rows with differing superscripts are different ($P < 0.10$)

[1] Treatments included CON-control; HIPRO20–20% high protein distillers grains; HIPRO40–40% high protein distillers grains; BRAN+SOL-40% corn bran plus solubles; DDGS-40% traditional dry distillers grains; WDGS-40% traditional wet distillers grains

[2] Average concentration over three time points (700 h, 1100h, 1500 h)

[3] Percent of total VFA

[4] Acetate:Propionate ratio

treatments. In the present experiment, dry distillers is not as digestible as wet distillers, particularly fiber digestion.

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Effects of Urea and Distillers Inclusion in Finishing Diets on Steer Performance and Carcass Characteristics

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Summary with Implications

An experiment was conducted to evaluate the effect of supplemental urea in dry rolled corn based finishing diets containing low inclusions of distillers grains. Treatments were set up in a 3 × 3 factorial arrangement. The first factor was wet distillers inclusion at either 10, 15, or 20% of diet DM. The second factor was urea inclusion at either 0, 0.5, or 1.0% of diet dry matter. Increasing inclusion of distillers linearly improved feed conversion and linearly reduced dry matter intake. An interaction for feed efficiency was observed where there was no effect of added urea when 10% or 20% distillers was fed and a quadratic effect was observed when 15% distillers grains was fed where 0.5% urea appeared to be optimum. Added urea in a finishing diet with 20 or 10% distillers has minimal impact on finishing performance; however, feeding 0.5% urea in a 15% distillers diet may be beneficial.

Introduction

Distillers grains are a good source of protein containing around 30% CP with 63% of this CP being rumen ungradable protein. With inclusions of distillers grains in finishing diets being greater than 25% over the past 10 years, protein has been over fed; therefore, meeting protein requirements (RDP and MP) hasn't been an issue. Previous research would suggest that when feeding distillers grains in dry rolled corn (DRC) based diets at greater than 25% of diet DM, no additional urea supplementation is needed to maintain animal performance. However, with increasing distillers grain price, inclusion of distillers has decreased to a level where adding supplemental urea may be beneficial. A recent survey suggested that, in the Midwest, the average inclusion of distillers in commercial feedlots is 19.9% of diet DM. Previous research has evaluated feeding 10 or 20% dry distillers with or without urea and they observed no performance response with added urea. However, there was a numerical improvement in feed conversion in the 10% distillers diet (*2005 Nebraska Beef Cattle Report*, pp 42–44).

With limited research on the topic, the objective of this research was to determine the effects of supplementing urea in dry rolled corn based finishing diets containing low inclusions of distillers grains.

Procedure

Four hundred and thirty two crossbreed steers were utilized in a study at the Panhandle Research and Extension Center near Scottsbluff NE. Treatments were set up in a 3×3 factorial arrangement with factors consisting of three distillers inclusions (10, 15, or 20% of the diet DM) and three urea inclusions (0, 0.5, or 1.0% of diet DM). Diets were dry-rolled corn (DRC) based using corn silage as the roughage source (Table 1). A liquid supplement was utilized and contained either 0 or 1% urea and the 0.5% urea treatment was accomplished by mixing a 50:50 blend of the 2 supplements. Cattle were fed once daily in the morning and managed on a slick bunk protocol. Rumensin (Elanco Animal Health) was supplied to the cattle at 360 mg/hd/d and Tylan (Elanco Animal Health) was supplied at 90 mg/hd/d added to the diet using a micro machine (Animal Health International). Three blocks were used with one replication in the light block, three replications in the middle block, and two replications in the heavy block. This design totaled 54 pens with 6 replications per treatment.

Blood was collected twice during the finishing period for plasma urea nitrogen (PUN) analysis. Blood was collected from three randomly selected animals per pen in the morning prior to feeding. These same three animals were used for both blood collections. The first blood collection was on d 28 of the finishing period after all cattle had been fully adapted onto their respective finishing diet. The second blood collection was on d 92 of the finishing period.

Cattle were implanted with a TE-IS (Elanco Animal Health) on d 28 and reimplanted with a TE-S (Elanco Animal Health) on d 90 of the finishing period. The Heavy block was on feed for 153 days and the light and mid blocks were on feed for 167 days. Cattle were slaughtered at a commercial abattoir (Cargill Meat Solutions, Fort Morgan, CO) and carcass data collected.

Data were analyzed using the mixed procedure of SAS for performance, carcass and blood variables with block and treatment as fixed effects. Blood data were analyzed as a repeated measure over time. Due to missing carcass data on the heavy block, data from that block were omitted from the carcass and carcass adjusted analysis of performance leaving 36 pens with 4 replications per treatment for these observations.

Results

Performance data are presented in Table 2. There were no significant interactions between distillers and urea inclusion ($P \geq 0.11$) with the exception of F:G so only the main effects are presented. There was a significant quadratic interaction ($P = 0.05$) between distillers and urea inclusion for carcass adjusted F:G (Figure 1). At 10% distillers, F:G appears to remain consistent as urea is increased in the diet. When feeding 15% distillers added urea appears to have a quadratic effect on F:G with lower F:G at 0.5% urea inclusion. For 20% distillers in the diet adding urea at 0.5% of the diet appears to have a negative impact on F:G while1.0% urea resulted in similar performance to the 0 urea control. This interaction would suggest that when

Table 1. Diet ingredient composition as % of diet DM by treatment

	10% Distillers			15% Distillers			20% Distillers		
Ingredient	0	0.5	1.0	0	0.5	1.0	0	0.5	1.0
DRC, % DM	69	69	69	64	64	64	59	59	59
WDGS, % DM	10	10	10	15	15	15	20	20	20
Corn Silage, % DM	15	15	15	15	15	15	15	15	15
Supplement[1] , % DM	6	5.5	5	6	5.5	5	6	5.5	5
Urea, % DM	0	0.5	1.0	0	0.5	1.0	0	0.5	1.0
Crude Protein, %	10.8	12.2	13.6	12.0	13.4	14.7	13.1	14.5	15.9
Initial MP Balance[2], g/d	-105	-47	8	-41	14	28	-6	94	39
Initial RDP Balance, g/d	-196	-54	86	-158	-19	118	-118	16	147
Midpoint MP Balance[2], g/d	-51	15	70	17	86	95	67	168	115
Midpoint RDP Balance, g/d	-210	-58	94	-170	-21	126	-127	17	158

[1] Micro machine was used to add 360 mg of Rumensin and 90 mg per steer of Tylan to the diet daily.

[2] Metabolizable Protein balance calculated using 1996 NRC Model to predict MP supply corrected for RDP balance deficiency if one existed (MP balance-(RDP balance*.64)). Initial MP balance is calculated for the end of the step up period and midpoint MP balance was calculated for the middle of the finishing period.

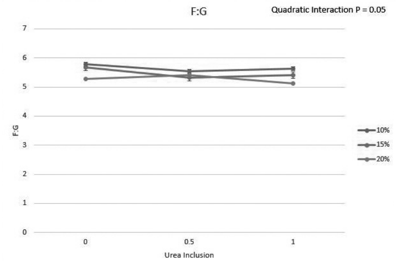

Figure 1. Carcass adjusted F:G interaction distillers level and urea inclusion.

feeding 10 or 20% distillers grains added urea in the diet has minimal benefit on performance but when feeding 15% distillers grains some added urea may be beneficial. However, with this type of interaction it is difficult to make conclusions and determine if the interaction is real or due to random variation in the data. Additionally, the missing carcass data from the heavy block of cattle may have had an effect on the data. A depression in animal performance for 20% distillers and 0.5% urea inclusion is the primary cause for the interaction, which is difficult to explain biologically.

The remaining performance variables were analyzed for main effects. For live performance, DMI and F:G decreased linearly ($P < 0.01$) with increasing inclusion of distillers grains. Additionally, a linear decrease ($P = 0.05$) in F:G was observed for increasing levels of urea in the diet. Visually, while not significant ($P = 0.26$) F:G appears to be quadratic with a plateau appearing at 0.5% urea. There was no difference ($P = 0.49$) in DMI observed for increasing urea levels. Average daily gain and final live weight increased linearly ($P < 0.03$) as distillers grains increased in the diet; however, ADG and final live weight tended to have a quadratic response ($P < 0.09$) with increasing levels of urea in the diet with maximum values at 0.5% inclusion.

For carcass adjusted performance, a tendency for a linear increase ($P \leq 0.08$) in final BW and ADG was observed for increasing levels of distillers grains. Both DMI and F:G linearly decreased ($P < 0.01$) as distillers grains was increased in the diet. Additionally F:G was linearly decreased ($P = 0.02$) with the addition of urea in the diet however, no other measures were significantly ($P \geq 0.14$) affected by urea inclusion.

A tendency for a linear increase ($P = 0.08$) in HCW was observed with increasing levels of distillers grains in the diet. Additionally, a linear increase ($P < 0.01$) in 12th rib fat thickness was observed with increasing levels of distillers grains in the diet. However, there were no other significant ($P \geq 0.15$) differences for carcass characteristic for either distillers or urea inclusion in the diet. Plasma urea nitrogen linearly increased ($P < 0.01$) for both added distillers and added urea in the diet. Others have found a minimum BUN value of 7 mg/100 mL to be necessary for optimum performance to be maintained. The values for the current trial are more than double (> 17.8) this value suggesting that there was more than enough excess nitrogen in the blood to maintain performance across all treatments.

Conclusion

Based on these results, when feeding 10 or 20% distillers grains in a finishing diet added urea is of limited benefit for animal performance. However, when feeding 15% distillers grains in the diet adding 0.5% urea to the diet appears to improve feed efficiency. However, it is difficult to explain the variation across 10, 15, and 20% inclusion. Our conclusion is that urea supplementation was unnecessary. Increasing inclusion of distillers grains in the diet even from 10 to 20% improved gain and reduced intake, thereby improving feed conversion.

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Table 2. Main effects of distillers inclusion and urea inclusion on performance

	Distillers, % diet DM				*P*-Value		Urea, % Diet DM				*P*-Value	
Measure	10	15	20	SEM	Lin	Quad	0%	0.5%	1.0%	SEM	Lin	Quad
Live Performance												
Initial BW, lb	617	616	615	1	0.06	0.94	617	616	616	1	0.22	0.75
Final BW, lb	1328	1337	1345	6	0.03	0.94	1328	1344	1338	6	0.19	0.09
ADG, lb/d	4.39	4.45	4.50	0.03	0.01	0.96	4.39	4.49	4.46	0.03	0.16	0.08
DMI, lb/d	24.1	24.0	23.4	0.2	<0.01	0.16	23.9	23.9	23.7	0.2	0.49	0.61
F:G	5.49	5.40	5.18	0.002	<0.01	0.25	5.43	5.32	5.32	0.002	0.05	0.26
Carcass Adjusted Performance												
Initial BW, lb	583	582	581	1	0.09	0.99	582	583	581	1	0.43	0.25
Final BW, lb	1277	1293	1298	8	0.08	0.63	1277	1298	1293	8	0.15	0.18
ADG, lb/d	4.16	4.25	4.29	0.05	0.06	0.65	4.16	4.28	4.26	0.05	0.14	0.24
DMI, lb/d	23.5	23.2	22.6	0.2	<0.01	0.55	23.2	23.3	23.0	0.2	0.45	0.46
F:G	5.65	5.46	5.26	0.002	<0.01	0.93	5.56	5.43	5.38	0.002	0.02	0.50
Carcass Characteristics												
HCW, lb	805	815	818	5	0.08	0.62	805	818	815	5	0.15	0.18
Dressing %	62.1	62.5	62.4	0.2	0.19	0.19	62.3	62.2	62.4	0.2	0.81	0.59
LM Area, in^2	13.7	14.0	13.8	0.2	0.43	0.24	13.8	13.8	13.9	0.2	0.74	0.63
12th Rib Fat, in	0.50	0.52	0.56	0.02	<0.01	0.84	0.53	0.52	0.52	0.02	0.75	0.89
Marbling	447	456	440	7	0.45	0.12	447	448	449	7	0.82	0.97
USDA Yield Grade	2.9	2.9	3.1	0.1	0.14	0.39	3.0	3.0	3.0	0.1	0.99	0.52
PUN mg/100mL[1]	18.57	20.03	22.72	0.53	<0.01	0.33	17.81	20.31	23.20	0.50	<0.01	0.73

[1] PUN = Plasma Urea Nitrogen

Effect of Adding Urea to Finishing Diets Containing Two Different Inclusions of Distillers Grains on Steer Performance and Carcass Characteristics

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Summary with Implications

The effects of adding urea to a dry rolled corn based finishing diet containing low inclusions of distillers grains was evaluated. Treatments were designed as a 2 × 4 factorial arrangement with factors consisting of wet distillers inclusion (either 12 or 20% of diet DM) and urea inclusion (0, 0.4, 0.8, 1.2% of diet DM). There were no significant interactions observed between distillers inclusion and urea inclusion in the diet. Increasing inclusion of distillers grains improved carcass adjusted average daily gain and feed conversion and reduced dry matter intake. Increasing distillers inclusion also increased 12th rib fat and had a tendency to increase hot carcass weight. There were no significant linear or quadratic responses for increasing urea inclusion in the diet. These data suggest that when feeding at least 12% distillers in the diet, supplemental urea has minimal impact on animal performance.

Table 1. Diet ingredient composition as % of diet DM by treatment

	12% Distillers				20% Distillers			
Ingredient	0	0.4	0.8	1.2	0	0.4	0.8	1.2
Dry-rolled corn	67	67	67	67	59	59	59	59
WDGS	12	12	12	12	20	20	20	20
Corn Silage	15	15	15	15	15	15	15	15
Supplement[1]	6	5.6	5.2	4.8	0	.4	.8	1.2
Urea[20]	0	0.4	0.8	1.2	6	5.6	5.2	4.8
Crude Protein, %	10.8	11.9	13.1	14.2	12.6	13.7	14.9	16.0
Initial MP Balance[3], g/d	-30	69	96	108	88	149	191	181
Initial RDP Balance g/d	-195	-77	46	171	-133	-13	106	225
Midpoint MP Balance[3], g/d	28	133	163	176	159	229	262	253
Midpoint RDP Balance, g/d	-210	-83	50	183	-142	-14	114	241

[1] Micro Machine used to add 360 mg/steer of Rumensin and 90 mg/steer of Tylan to the diet daily.

[2] Urea was included in the supplement, therefore, the total supplement included in the diet was the sum of the urea and supplement rows for the respective treatment. A total of 6% of diet DM of the supplement was included in all diets.

[3] Metabolizable Protein balance calculated using 1996 NRC Model to predict MP supply corrected for RDP balance deficiency if one existed (MP balance-(RDP balance*.64)).Initial MP balance is calculated for the end of the step up period and midpoint MP was calculated for the middle of the finishing period.

Introduction

Distillers grains is a good source of protein in finishing diets. However, the majority of protein in distillers grains is in the form of rumen undegradable protein (RUP) which may create a deficiency in rumen degradable protein (RDP) in diets where low inclusions of distillers are used. However, when RUP is fed at levels that exceed the animal's requirement, the amine group from the excess protein can be removed and the nitrogen can be recycled back to the rumen and alleviate a RDP deficiency. Previous research would suggest that when feeding distillers grains in dry rolled corn (DRC) based diets at greater than 25% of diet DM, no additional urea supplementation is needed to maintain animal performance. Additionally, research evaluating the impact of adding urea to finishing diets containing 10, 15, or 20% distillers grains observed minimal impact in adding urea to dry rolled corn based (*2019 Nebraska Beef Cattle Report*, pp. 97–99). Likewise, other research evaluated feeding 10 or 20% dry distillers grains with or without urea and suggested that there was no average daily gain (ADG) response with added urea. However, there was a numerical improvement in feed conversion for cattle fed 10% distillers diet with urea (*2005 Nebraska Beef Cattle Report*, pp. 42–44).

With limited research on the topic and with more producers using 10 to 20% distillers in diets (DM basis), the objective of this research was to determine the effects of supplementing urea in dry rolled corn based finishing diets containing 12 or 20% distillers grains.

Procedure

Three hundred and eighty four crossbreed steers were utilized in a study at the Panhandle Research and Extension Center near Scottsbluff NE. Treatments were set up in a 2 × 4 factorial arrangement with factors consisting of two distillers inclusion (12 or 20% of the diet DM) and four urea inclusions (0, 0.4, 0.8, and 1.0% of diet DM). Diets were DRC based using corn silage as the roughage source (Table 1). A liquid supplement containing either 0 or 1.2% urea was utilized and the 0.4% and 0.8% urea treatments contained a blend of the 0 and 1.2% urea supplements. Cattle were fed once daily in the morning and fed ad libitum. Rumensin was supplied at 360 mg/steer and Tylan was supplied at 90 mg/steer daily using a micro machine (Animal Health International).

Cattle were limit fed a common diet for 5 days prior to the first initial weight at an estimated 2% of BW. Cattle were weighed on d 0, blocked by BW and assigned randomly to pen and pen assigned randomly to treatment based off of this weight. Cattle were then weighed again on d 1 and sorted into their respective pen. Three blocks were used with one replication in the light block, three replications in the middle block, and two replications in the heavy block. This

Table 2. Main effects of dietary urea inclusion on animal performance and carcass measurements

	Urea						*P*-Value		
Item	0%	0.4%	0.8%	1.2%	SEM	*P*-Value	Lin	Quad	Cubic
Live Performance									
Initial BW, lb	633	633	634	635	1.1	0.40	0.11	0.66	0.68
Final BW, lb	1358^{ab}	1386^{a}	1336^{b}	1354^{ab}	13.5	0.07	0.29	0.70	0.02
ADG, lb	4.21^{ab}	4.37^{a}	4.07^{b}	4.17^{ab}	0.077	0.07	0.24	0.71	0.02
DMI, lb/d	25.4	25.9	25.1	25.5	0.28	0.26	0.74	0.84	0.05
F:G	6.02	5.92	6.13	6.10	-	0.36	0.28	0.73	0.16
Carcass Adjusted Performance									
Initial BW, lb	633	633	634	635	1.1	0.40	0.11	0.66	0.68
Final BW, lb	1374^{ab}	1395^{a}	1353^{b}	1377^{ab}	9.7	0.03	0.44	0.87	0.004
ADG, lb	4.30^{ab}	4.41^{a}	4.17^{b}	4.30^{ab}	0.06	0.03	0.34	0.83	0.005
DMI, lb/d	25.4	25.9	25.1	25.5	0.28	0.26	0.74	0.84	0.05
F:G	5.88	5.85	6.02	5.92	-	0.23	0.36	0.63	0.08
Carcass Characteristics									
HCW, lb	866^{ab}	878^{a}	852^{b}	867^{ab}	6.1	0.03	0.44	0.85	0.005
Dressing %	63.7	63.5	63.8	64.1	0.5	0.87	0.54	0.61	0.77
LM Area, in^{2}	13.6	14.0	13.8	13.8	0.1	0.26	0.57	0.24	0.13
12th Rib Fat, in	0.57	0.57	0.53	0.56	0.02	0.55	0.62	0.41	0.28
Marbling[1]	482	488	481	488	9.4	0.93	0.80	0.95	0.53
USDA YG	3.3	3.3	3.2	3.3	0.08	0.46	0.40	0.24	0.48

Values within row with similar superscripts are not different (P > 0.05)

[1] 300 = slight, 400 = Small, 500 = Modest.

totaled 48 pens with 8 steers/pen, and 6 replications per treatment.

Cattle were implanted with a TE-IS (Elanco Animal Health) on day 1 and reimplanted with TE-200 (Elanco Animal Health) on d 98 of the finishing period. The heavy block was on feed for 162 d and the light and mid blocks were on feed for 180 d. Cattle were slaughtered at a commercial abattoir (Cargill Meat Solutions, Fort Morgan, CO). Kill order and HCW were collected on day of slaughter and carcass data were collected after a 48 hr chill.

Performance and carcass data were analyzed using the MIXED procedure of SAS with block and treatment as fixed effects. Interactions between distillers and urea inclusion were tested and if not significant the main effects of treatment were investigated. Linear and quadratic effect of urea inclusion was analyzed using contrast statements.

Results

There were no significant interactions ($P \geq 0.14$) between distillers and urea inclusion for final body weight (BW), ADG, dry matter intake (DMI), feed conversion (F:G), or carcass characteristics, therefore, only the main effects of distillers level and urea level are presented (Table 2 and Table 3). Increasing inclusion of distillers grains from 12 to 20% improved F:G ($P < 0.01$) on both a live and carcass adjusted basis. Increasing inclusion of distillers grains increased carcass adjusted ADG ($P = 0.04$). Live ADG was numerically increased ($P = 0.20$) but was not significantly different due to greater variation. Increasing inclusion of distillers decreased DMI ($P = 0.04$) and had a tendency ($P = 0.07$) to increase carcass adjusted final BW. There was a tendency ($P = 0.07$) for increasing distillers grains to increase HCW. Increasing distillers grains increased both USDA yield grade and 12th rib fat ($P = 0.04$) but had no effect ($P > 0.63$) on other carcass measures.

Cubic responses were observed for increasing urea inclusions in the diet for many performance measures; however, a cubic effect is of minimal biological relevance as it signifies a measure that is going up and down as you add urea in the diet. In the current trial, these cubic effects are likely associated with random variation that occurred mostly at the 0.8% inclusion of urea where a decrease was observed in ADG and increase in F:G before going the opposite direction at the 1.2% inclusion rate. There were no significant ($P \geq 0.11$) linear or quadratic responses observed for any performance or carcass measure for increasing urea inclusion. There was a significant main effect ($P < 0.03$) for carcass adjusted final BW, ADG and HCW across urea inclusions suggesting variation due to imposed treatments. There was no difference in these measures for the 0, 0.4, and 1.2% urea in the diet; however, the 0.8% urea inclusion decreased these measures when compared to the 0.4% inclusion level but was not different than the 0 or 1.2% urea levels. Conservatively, adding 0.4% urea may be an opportunity with low distillers grains diets, but the response observed above 0.4% urea inclusion needs to be repeatable.

Conclusion

Increasing distillers grains in the diet improved ADG, F:G, and tended to increase HCW. Adding urea to the diet had minimal impact on animal performance

Table 3. Main effects of dietary distillers inclusion on animal performance and carcass measurements

	Distillers Inclusion			
Measure	12	20	SEM	*P*-Value
Live Performance				
Initial BW, lb	634	633	0.8	0.36
Final BW, lb	1350	1367	9.8	0.22
ADG, lb	4.16	4.26	0.056	0.20
DMI, lb/d	25.7	25.2	0.20	0.04
F:G	6.21	5.92	-	0.01
Carcass Adjusted Performance				
Initial BW, lb	634	633	0.8	0.36
Final BW, lb	1366	1383	7.0	0.07
ADG, lb	4.24	4.35	0.04	0.04
DMI, lb/d	25.7	25.2	0.20	0.04
F:G	6.06	5.78	-	0.001
Carcass Characteristics				
HCW, lb	860	872	4.5	0.07
Dressing %	63.7	63.9	0.4	0.79
LM Area, in^2	13.8	13.8	0.1	0.63
12th Rib Fat, in	0.54	0.58	0.01	0.04
Marbling[1]	486	484	6.8	0.80
USDA Yield Grade	3.18	3.35	0.06	0.04

[1] 300 = slight, 400 = Small, 500 = Modest.

and while there was a reduction in performance at 0.8% inclusion level, this response is not easy to explain. With improved performance, it may be economical to include at least 20% distillers grains in a dry rolled corn based finishing diet as distillers grains not only provides protein to the diet but also added energy. When feeding at least 12% distillers grains in a DRC based finishing diet adding supplemental urea is of limited benefit.

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Pooled Analysis of Individually Fed Finishing Trials

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Summary with Implications

A pooled analysis of 21 finishing trials (2002–2016; 1530 animals) with cattle individually fed in Calan gate barns was conducted. Mixed model regression analysis following random coefficient methodology was used to evaluate relationships between performance variables and carcass characteristics. Gain had a greater effect on efficiency ($R^2 = 0.72$) compared to intake ($R^2 = 0.02$). The relationship between gain and efficiency was cubic, while intake had a quadratic relationship. The cubic response of gain relative to efficiency was continually increasing with relatively slight curves in the line heavily influenced by points that lay on the ends of the data. Efficiency also had cubic relationships with fat thickness and marbling of carcasses; however, the regressions had low R^2 values of 0.01. There was a significant relationship between efficiency and fat thickness and marbling, but the variation around the trend line was high. Efficiency alone is a poor predictor of fat thickness and marbling.

Introduction

Feeding cattle in a pen setting limits data collection on individual animal performance. In pen fed studies, the experimental unit is the pen. When cattle are individually fed, dry matter intake (DMI) and average daily gain (ADG) are collected on the individual, which makes the experimental unit the animal instead of the pen. When using data from individually fed animals the variation due to animal is more apparent and can be compared to the variation from a pen of animals.

The purpose of this analysis was to examine: 1) the effect of DMI and ADG on feed to gain (F:G), 2) the effect of F:G on fat thickness and marbling. This analysis was done with individually fed cattle which gives a better understanding of how individual animals perform.

Procedure

A pooled analysis of 21 previous studies performed at the University of Nebraska–Lincoln Eastern Nebraska Research and Extension Center, near Mead, NE, was conducted. The data were collected at the individually fed barns equipped with the Calan gate system. Trials selected were finishing trials conducted from 2002 through 2015. There were 5 trials with intact heifers, 1 trial with spayed heifers, and 15 trials with steers. Initial body weight (BW) ranged from 496 to 1195 lb with a mean starting weight of 822 lb. Initial BW was taken after a 5 day limit feeding period in all trials and cattle were weighed 3 consecutive days with the exception of 1 trial which started as a growing trial and cattle were stepped up directly to a finishing diet. Fifteen of the trials utilized 60 animals, 5 trials utilized 120 animals, and 1 trial utilized 30 animals (n = 1530). Diets for each trial were replicated 5 to 40 times with 18 of the trials having 10 to 20 replications per treatment. Animals were on feed for 93 to 189 days.

All cattle were shipped to the same abattoir (Greater Omaha Packing Co., Omaha, NE) for harvest and carcass data collection. Hot carcass weight (HCW) and liver scores were collected at the time of harvest. Marbling score, 12th rib fat thickness (FT), and longissimus muscle (LM) area were collected following a 48 hour chill. Final BW was calculated from HCW using a common 63% dressing percentage. Cattle ADG and F:G were calculated from this adjusted final BW.

Mixed model regression analysis following random coefficient methodology was used to evaluate relationships between variables. Factors of interest were: impact of DMI and ADG on F:G and relationships between F:G of cattle and FT or marbling.

For each analysis, there was a dependent and independent variable with the linear, quadratic, and cubic terms in the model. If the type 3 fixed effect for the cubic term was not significant ($P > 0.10$), the model was reduced to just the quadratic and then the linear term. If the model was reduced to the linear term and there was no significance, then it was assumed that no correlation existed between the dependent and independent variables.

When statistics indicated a model was significant ($P < 0.10$), the estimates from the fixed effects were used as coefficients to create regression lines. The significance of term was used to determine if the coefficient of each term was different from zero. Residuals from random effects were then added to the regression line prediction from each independent variable to calculate trial adjusted dependent variables.

Results

Effect of DMI and ADG on Feed Conversion

Feed conversion is described as the amount of feed consumed per equal unit of body weight gained (F:G = DMI/ADG). Typically, as DMI increases in finishing animals, ADG increases at a decreasing rate; ADG increased quadratically as DMI increased in the current dataset. However, the relationship between DMI and F:G or ADG and F:G is not as well understood. Because DMI and F:G were measured in individually fed animals in the current analysis, these relationships can be observed.

The relationship between F:G and DMI was quadratic ($P < 0.01$; $R^2 = 0.02$; Figure 1). However, the relationship between F:G and ADG was cubic ($P < 0.01$; $R^2 = 0.71$; Figure 2). The linear relationship between F:G and ADG ($P < 0.01$; $R^2 = 0.55$) may be more biologically relevant as data at the ends of the range are likely overly influencing the response. Cattle with very high F:G may have been sick or internally injured.

More variation in F:G was accounted for by ADG ($R^2 = 0.71$) compared to DMI ($R^2 = 0.02$). This indicates that ADG is more influential at determining F:G in finishing beef cattle than DMI. In the current analysis, F:G continually improved as ADG increased.

Effect of Performance on Fat Thickness and Marbling

Relationships between F:G and carcass characteristics are not well documented. It is not clear if more efficient animals also have greater FT or marbling. The relationship between F:G and FT was quadratic ($P < 0.01$; $R^2 = 0.01$; Figure 3) and the relationship between F:G and marbling score was cubic ($P < 0.01$; $R^2 = 0.01$; data not shown). Although statistics indicated a significant trend, using F:G alone is still a poor predictor of how an animal will deposit subcutaneous ($R^2 = 0.01$) and intra-muscular fat ($R^2 = 0.01$).

The relationship between FT and marbling was a quadratic response ($P < 0.01$; $R^2 = 0.14$; Figure 4). As FT increased, marbling score increased at a decreasing rate. This quadratic response is heavily influenced by only a few animals that had greater than 0.83 in of FT.

Conclusion

This analysis provides evidence that cattle gain has more influence on efficiency of cattle than intake. Feed efficiency of animals had little effect on carcass traits, within feedlot diets with typical energy content. However, marbling score increased with increased back fat thickness.

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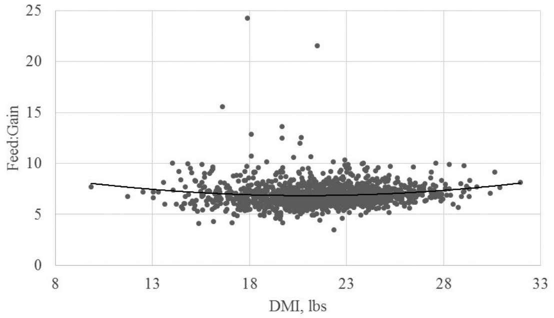

Figure 1. Relationship between feed to gain (F:G) and dry matter intake (DMI) of individually fed finishing cattle.
$\text{F:G} = 0.01 \pm 0.07 \times \text{DMI}^2 - 0.415 \pm 0.065 \times \text{DMI} + 11.17 \pm 3.22$ ($R^2 = 0.02$).

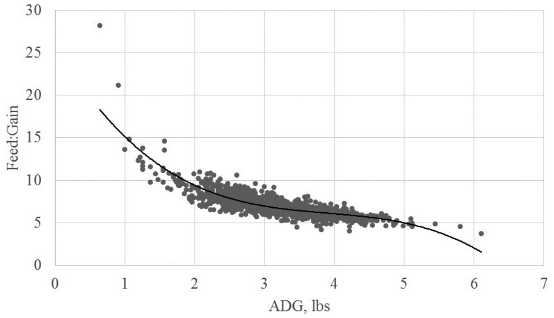

Figure 2. Relationship between feed to gain (F:G) and average daily gain (ADG) of individually fed finishing cattle.
$\text{F:G} = -0.287 \pm 0.041 \times \text{ADG}^3 + 3.35 \pm 1.81 \times \text{ADG}^2 - 13.78 \pm 2.65 \times \text{ADG} + 25.8 \pm 14.1$ ($R^2 = 0.71$)

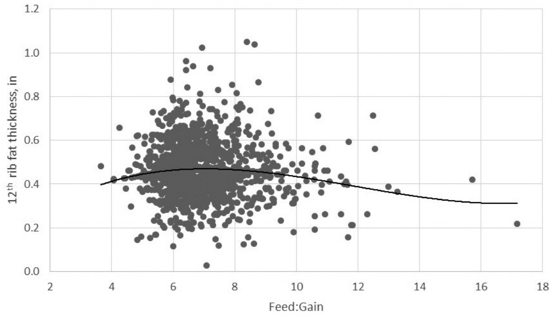

Figure 3. Relationship between feed to gain (F:G) and 12th rib fat thickness (FT) of individually fed finishing cattle.
$\text{FT, in} = 0.0003 \pm 0.0001 \times \text{F:G}^3 - 0.013 \pm 0.006 \times \text{F:G}^2 + 0.124 \pm 0.064 \times \text{F:G} + 0.095 \pm 0.087$ ($R^2 = 0.01$)

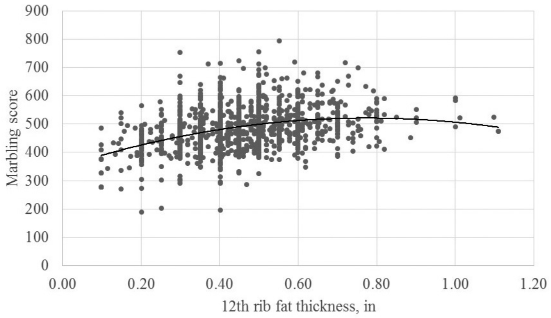

Figure 4. Relationship between 12th rib fat thickness (FT) and marbling score of individually fed finishing cattle. Marbling score: 300 = slight, 400 = small, 500 = modest, etc.
$\text{Marbling score} = -289.01 \pm 62.01 \times \text{FT}^2 + 447.83 \pm 65.41 \times \text{FT} + 374.75 \pm 19.92$ ($R^2 = 0.14$).

Comparison of Traditional and Alternative Curing Ingredients on Curing Reactions in a Model Meat System

Faith D. Rasmussen
Gary A. Sullivan

Summary with Implications

To meet consumer trends, alternative curing ingredients are used to replace sodium nitrite and cure accelerators. Due to the complexity of meat, it is challenging to compare traditional and alternative ingredients for curing reactions. Using a model system, sources of nitrite (traditional, sodium nitrite and alternative, cultured celery juice powder), salt, and cure accelerators (traditional, sodium erythorbate, or alternative, cherry juice powder) at ingoing sodium nitrite concentrations of 10, 50, 100, 150, or 200 ppm were evaluated for curing reactions. More complete curing reactions were indicated by a higher concentration of cured meat pigment, and lower sulfhydryl groups. Lower residual nitrite indicates reduction of nitrite into nitric oxide, and higher reducing capacity indicates a higher concentration of antioxidants. Traditional nitrite and celery juice powder treatments had similar concentrations of residual nitrite and cured meat pigment. Celery juice powder treatments with and without a cure accelerator had the most sulfhydryl groups and a high residual reducing capacity. This research demonstrates cultured celery juice powder and cherry powder develop similar concentrations of cured meat pigment as traditional sodium nitrite and sodium erythorbate, but antioxidants native to alternative ingredients may lessen the production of nitrosated cysteine.

Introduction

In meat curing, many reactions occur between the meat, nitrite, and other added ingredients. These reactions contribute to familiar cured meat characteristics such as color, flavor, aroma, and safety. Traditional curing processes utilize sodium nitrite. Nitrite reacts with myoglobin in meat, to produce the pink cured meat pigment nitrosylhemochromagen. Nitrite also reacts with sulfur-containing proteins in the meat, specifically cysteine, to generate nitrosated cysteine. The speed of these reactions is increased by adding a cure accelerator. Sodium erythorbate is typically used as a cure accelerator in processed meat manufacturing but natural sources of ascorbic acid, such as cherry juice powder, can provide a similar function.

Consumer demand for natural products is increasing, and traditional curing ingredients are being replaced with alternative ingredients to produce cured meat products. Synthetic sodium nitrite can be replaced with cultured celery juice powder, and sodium erythorbate can be replaced with ascorbic acid from acerola cherries. While similar product characteristics can be achieved with traditional or alternative sources of curing ingredients, tracking specific reactions can allow for a more detailed understanding of the equivalency of traditional and alternative ingredients. The objective of this study was to evaluate the effects of curing solutions containing either traditional sources of nitrite and cure accelerators, or alternative sources of nitrite and cure accelerators and the effect of ingoing nitrite concentration on curing reactions in model meat systems.

Procedure

The project used a factorial arrangement of treatments: 2 meat model solutions, 5 curing system solutions, and 5 ingoing nitrite concentrations. The meat model solutions were cysteine (615 ppm) and cysteine plus myoglobin (615 ppm and 48 ppm, respectively), in a 5.6 pH phosphate buffer. Using the two meat model solutions provided the ability to decipher differences in reactions with each component. Solutions were evaluated representing different curing systems. The three traditional curing system solutions were evaluated: sodium nitrite (SN), sodium nitrite with sodium chloride (NaCl) to equal the salt contained in celery juice powder treatments (SN/NA), sodium nitrite with NaCl and sodium erythorbate (equivalent to 547 ppm; SN/SE). Two alternative curing system solutions were developed for comparison against the traditional systems: celery juice powder (VegStable 504, Florida Food Products, Inc., Eustis, FL; CP), and celery juice powder and acerola cherry powder (VegStable 515 to provide 486 ppm ascorbic acid; CP/CH.). The curing system solutions were evaluated at ingoing nitrite concentrations of 10, 50, 100, 150, and 200 ppm of sodium nitrite or equivalent from celery juice powder.

A curing solution (5 ml) was added to each model meat solution (5 ml) in 13 ml test tubes, capped, heated in a water bath (30 min at 104°F, and 30 min at 176°F), and air cooled (15 min at 73°F) to simulate meat curing during the cooking. All model curing solutions were analyzed for residual nitrite, residual sulfhydryl groups, and residual reducing capacity (DPPH neutralized). In addition, the model meat curing solutions containing myoglobin were evaluated for cured meat pigment concentration (nitrosylhemochromogen).

The experiment was conducted as a completely randomized design with a factorial treatment arrangement and three independent replications. Data were analyzed using the GLIMMIX procedure of SAS. Interactions of effects and main effects of model meat solution (cysteine, or cysteine and myoglobin), curing system (SN, SN/NA, SN/SE, CP, CP/CH), and ingoing nitrite concentration (10, 50, 100, 150, or 200 ppm) were analyzed. When significant interactions or main effects were identified ($P \leq 0.05$), means separation was conducted using the post hoc adjustment of Tukey honestly significant difference test.

Results

Nitrite reactions: Cured Meat Pigment and Residual Sulfhydryl Groups

In this system, curing reactions occur with nitrite, myoglobin, and the amino acid cysteine. Cure accelerators increase the rate and extent of the reactions. Nitrite reactions

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Table 1. Influence of curing system and ingoing nitrite concentration on cured meat pigment and residual reducing capacity (reflected as DPPH Neutralized) using a model meat curing system

Curing System[1]	Cured Meat Pigment (ppm)	Residual reducing capacity (DPPH Neutralized (μM))
SN	15.96^{b}	2.98^{d}
SN/NA	18.18^{b}	3.14^{cd}
SN/SE	19.23^{ab}	4.98^{b}
CP	16.76^{b}	3.46^{c}
CP/CH	22.57^{a}	6.65^{a}
Standard error	0.99	1.00

Ingoing nitrite concentration (ppm)	Cured meat pigment (ppm)	Residual reducing capacity (DPPH neutralized (μM))
10	13.4^{y}	4.65^{x}
50	17.85^{x}	4.41^{xy}
100	19.71^{x}	4.18^{yz}
150	20.52^{x}	4.01^{yz}
200	21.22^{x}	3.93^{z}
Standard error	0.97	1.00

[1] SN-sodium nitrite, SN/NA-sodium nitrite and sodium chloride SN/SE-Sodium nitrite, sodium chloride and sodium erythorbate, CP-Cultured celery juice powder, CP/CH-Cultured celery juice powder and acerola cherry juice powder

[a-d] For curing system main effect, means within a column without a common superscript are significantly different ($P < 0.001$)

[x-z] For ingoing nitrite concentration main effect, means within a column without a common superscript are significantly different ($P < 0.001$)

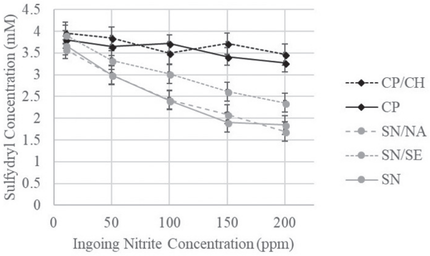

Figure 2. Interaction of curing system and ingoing nitrite concentration on residual sulfhydryl groups in a model meat curing system. SN-sodium nitrite, SN/NA-sodium nitrite and sodium chloride SN/SE-Sodium nitrite, sodium chloride and sodium erythorbate, CP-Cultured celery juice powder, CP/CH-Cultured celery juice powder and acerola cherry juice powder. Error bars indicate ± standard error.

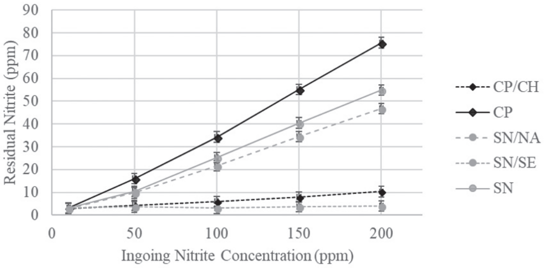

Figure 1. Interaction of curing system and ingoing nitrite concentration on residual nitrite in a model meat curing system. SN-sodium nitrite, SN/NA-sodium nitrite and sodium chloride SN/SE-Sodium nitrite, sodium chloride and sodium erythorbate, CP-Cultured celery juice powder, CP/CH-Cultured celery juice powder and acerola cherry juice powder. Error bars indicate ± standard error.

with myoglobin result in the production of cured meat pigment (nitrosylhemochromagen) and nitrite reactions with cysteine produce nitrosated cysteine result in fewer residual sulfhydryl groups. As nitrite is consumed by reactions in the system, lower residual nitrite levels occur.

In this experiment, the main effects of curing system and ingoing nitrite concentration were significant for cured meat pigment ($P < 0.001$; Table 1). Treatments containing cure accelerators (SN/SE and CP/CH) had greater concentrations of cured meat pigment indicating that a greater portion of the total myoglobin reacted with nitrite. The amount of cured meat pigment was greater when ingoing nitrite increased from 10 to 50 ppm but did not increase further when greater than 50 ppm of nitrite was added.

An interaction between curing system and ingoing nitrite concentration also was identified for the concentration of residual sulfhydryl groups ($P < 0.001$; Figure 1). At 10 ppm, all curing systems were similar. As ingoing nitrite concentration increased, curing systems containing celery juice powder had more residual sulfhydryl groups (CP, CP/CH) than any treatment with sodium nitrite (SN, SN/NA, SN/SE). The SN/SE treatment was intermediate and traditional curing systems without sodium erythorbate (SN, SN/NA) had the least residual sulfhydryl groups; suggesting cure accelerators (reducing compounds) or other antioxidant compounds in cultured celery juice powder could shift nitrosating reactions to produce less nitrosated cysteine.

Residual Nitrite

An interaction between curing system and ingoing nitrite concentration occurred for residual nitrite concentration ($P < 0.05$; Figure 2). At 10 ppm, no differences between curing systems could be identified but as the concentration of ingoing nitrite increased, differences between curing systems were identified. Curing systems without cure accelerators (SN, SN/NA, CP) displayed greater concentrations of residual nitrite than those with cure accelerators (SN/SE, CP/CH), and residual nitrite concentration increased with increasing ingoing nitrite concentration. This can be explained by cure accelerators increasing the reduction of nitrite to nitric oxide to react with components of the model meat system as would occur during meat curing.

Residual Reducing Capacity

For residual reducing capacity, measured by DPPH neutralized, the main effects of curing system and ingoing nitrite concentration were significant ($P < 0.001$; Table 1). The CP/CH curing solution had the most residual reducing capacity followed by the SN/SE; these had added cure accelerators which are reducing compounds. Celery juice treatments had more residual reducing capacity than the traditional alternatives, indicating native antioxidant compounds in the powders. As ingoing nitrite concentration increased the residual reducing capacity decreased since more could be utilized to reduce nitrite to nitric oxide with greater ingoing nitrite concentrations.

Meat System Effect on Residual Nitrite and Sulfhydryl groups

The cysteine model meat solution had less residual nitrite and less remaining sulfhydryl groups than the cysteine and myoglobin model solution ($P < 0.001$), suggesting the reaction of nitrite with myoglobin occurs before the reaction with cysteine.

Conclusions

Results from this model system can be used to better explain the curing reactions that occur between nitrite, myoglobin, and sulfur-containing amino acids in meat. Traditional and alternative curing ingredients developed similar cured meat pigment, especially when cure accelerators were used. However, the use of cultured celery juice powder and acerola cherry juice powder resulted in less nitrosated cysteine, indicating that native antioxidants might influence the reactions between nitrite and sulfur-containing amino acids. This experiment helps provide a better understanding of the equivalency of traditional or alternative nitrite sources and can be used in combination with previous research to provide better recommendations to processors who are interested in producing alternatively cured beef products.

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Quality Effects on Beef from Cattle Fed High-Protein Corn Distillers Grains and Other Ethanol By-Products

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Summary with Implications

The objective of this study was to evaluate the effects of feeding high protein corn distillers grains on fresh beef quality. Steers were fed one of five diets, either a corn control, high protein distillers grains plus solubles, dry distillers grains plus solubles, wet distillers grains plus solubles, or bran plus solubles diet. Strip loins were aged for 2, 9, or 23 days and placed under retail display conditions for 0 or 7 days. Dietary treatment had no effect on tenderness within each aging period. There were also no differences between treatments for proximate composition, free calcium in the muscle, and sarcomere length. Results suggest that feeding high protein distillers grains decreases color stability and increases lipid oxidation when compared to corn diets leading to reduced shelf life.

Introduction

Feeding distillers grains from ethanol production to cattle has been widely implemented since distillers grain has been reported to have a better feeding value than corn. However, previous research has shown that feeding distillers grains to cattle can increase polyunsaturated fatty acid content in muscle, resulting in greater discoloration and lipid oxidation in strip loins leading to reduced shelf life. Recently, the ethanol industry has adopted a process called dry fractionation, which separates the corn kernel into its germ, bran, and endosperm. The endosperm is the sole fraction introduced into the ethanol production process resulting in distillers grain with higher crude protein levels due to more efficient fermentation. The quality effects of feeding this type of distillers grain are not widely understood. Therefore, the purpose of this study was to determine the quality effects on beef from cattle fed high protein distillers grains.

Procedure

A total of 300 steers were allocated in 30 pens (10 hd/pen) and fed one of five diets for 190 days: a corn control diet (Control), or a diet containing 40% high protein dry distillers grains plus solubles (HP-DDGS), 40% dry distillers grains plus solubles (DDGS), 40% wet distillers grains plus solubles (WDGS), or 40% bran plus solubles (Bran) diet. Inclusion rates of distillers grains were calculated on a dry matter basis. Eighteen USDA Choice carcasses (3 hd/pen) were randomly selected within each treatment (n=90). Hot carcass weight at harvest was 862 lbs (SD 69.7 lbs). Strip loin samples from the right side were collected and divided into three sections and randomly assigned to one of the three aging periods (2, 9, or 23 d). Three one-inch steaks were fabricated at each aging period [one steak for tenderness measurement for 0 d of retail display, one steak for WBSF, visual discoloration, and objective color for 7 d of retail display, and one steak was cut in half for lipid oxidation for 0 d of retail display and all other laboratory analysis]. A one half-inch steak was cut in half and utilized for lipid oxidation after 4 and 7 d of retail display. After fabrication all steaks used for WBSF, color analysis, and lipid oxidation were placed on foam trays, overwrapped with oxygen permeable film, and placed under retail display conditions for 7 d at 37°F.

For all steaks (never frozen), internal raw temperature and weight were recorded. Steaks were cooked to 80°F and turned over until they reached a target temperature of 160°F on an indoor grill (Hamilton Beach-31605A, Hamilton Beach Brands, Glen Allen, VA). After cooking, internal temperature and weight were recorded. The steak was then bagged and stored in the cooler (33°F) for approximately 24 hours. Six cores (1/2-inch diameter) were removed parallel to the muscle fiber orientation and were sheared with a Food Texture Analyzer with a Warner-Bratzler blade to determine Warner-Bratzler shear force (WBSF).

Objective color was measured daily for 7 d using a Minolta Colorimeter (CR-400, Minolta Camera Company, Osaka, Japan). The D65 illuminant setting and 2° observer with an 8 mm diameter measurement area were used. Color values were obtained by averaging 6 readings from various areas of the steak surface. The CIE L*, a*, and b* values correspond to lightness, redness, and yellowness, respectively. Visual discoloration was evaluated daily for 7 d on a scale from 0–100% discoloration by 5 trained panelists.

Thiobarbituric acid reactive substance values (TBARS) were measured for all aging periods at 0, 4, and 7 d of display. Duplicate five gram samples of powdered strip loin steak with no subcutaneous fat were measured. Results were expressed in mg of malonaldehyde per kg of muscle tissue.

Sarcomere length was measured for powdered muscle samples aged for 2 d with 0 d of retail display by the laser diffraction method. Results were expressed in µm.

Moisture and ash (%) of lean muscle (no subcutaneous fat) were quantified with a LECO Thermogravimetric Analyzer in duplicate (Model 604–100–400, LECO Corporation, St. Joseph, MI). Fat content was quantified in triplicate by ether extraction according to the Soxhlet procedure.

Ten grams of powdered sample were weighed out in duplicate and 90 mL of distilled, deionized water was added along with a magnetic stir bar. The samples were mixed continuously throughout the measurement process. Sample pH was measured using a calibrated pH meter (Orion 410Aplus, ThermoFisher Scientific, Waltham, MA). Values of the duplicated samples were averaged for a final pH value

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for all aging periods with 0 d of retail display.

Three grams of powdered sample were centrifuged at 196,000 x g (Beckman Optima XPN-90 Ultracentrifuge, Type 50.2 Ti rotor, Beckman Coulter, Brea, CA) at 40°F for 30 minutes. Seven hundred µL of the supernatant were collected and treated with 0.1 mL of 27.5% trichloroacetic acid (TCA). Samples were centrifuged at 6,000 x g (accuSpin Micro 17R, ThermoFisher Scientific, Waltham, MA) for 10 min. Four hundred µL of supernatant were transferred to a syringe, and the volume was brought to 4 mL with deionized, distilled water. The diluted sample was filtered through a 13 mm diameter Millex-LG 0.20µm syringe filter (Milliore, Bedford, MA). Calcium concentration was quantified using an inductively-coupled plasma emission spectrometer (iCAP 6500 Radial; Thermo Electron, Cambridge, UK) with appropriate calcium concentration standards.

Objective and subjective color data were analyzed as a split-plot repeated measures design with dietary treatment as the whole-plot, aging period as the split-plot and retail display time as the repeated measures. Tenderness and lipid oxidation data were analyzed as 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. Proximate analysis and sarcomere were analyzed as a complete random design. Free calcium and pH were analyzed as 5 x 3 factorial arrangement of treatments. Data were analyzed using the PROC GLIMMIX procedure of SAS and pen was the experimental unit. All means were separated with the LS MEANS statement and the TUKEY adjustment with an alpha level of 0.05 and tendencies were considered at an alpha level of 0.1.

Results

There were no tenderness differences among diets within the same aging periods. The only effects observed for tenderness were in regards to retail display, indicating an increase in tenderness as time in retail display conditions increased (2 d: $P < 0.0001$, 9 d: $P = 0.0002$, 23 d: $P < 0.0001$, respectively).

Muscle L* and a* exhibited dietary treatment by retail display interactions ($P = 0.0005$, and $P < 0.001$, respectively). The L* values for steaks from cattle fed WDGS were greater (lighter; $P < 0.05$) than all treatments at 0 d of retail display other than steaks from cattle fed HP-DDGS, which was similar. There were no differences ($P > 0.05$) in lightness among any of the other treatments at day 0 of retail display. After 7 d of retail display, steaks from cattle fed HP-DDGS had greater L* values than steaks from the Control cattle ($P = 0.004$). Redness (a*) values were greater ($P < 0.05$) for steaks from cattle fed DDGS than both steaks from the Bran treatment and Control after 0 d of retail display. The HP-DDGS steaks had lower ($P > 0.05$) redness values than all other treatments following 7 d of retail display while steaks from Control-fed cattle had the greatest a* value ($P < 0.05$). In general, a lighter, redder beef color is preferred. A 3-way interaction of dietary treatment, aging, and retail display was identified for b* values ($P = 0.006$). At 2 and 23 d aging with 0 d retail display there were no differences among dietary treatments ($P > 0.05$). However, during 9 d of aging with 0 d of retail display steaks from cattle supplemented with DDGS was significantly more yellow (greater b* value) than steaks from Control-fed cattle ($P = 0.03$). For steaks with 2 d of aging and 7d of retail display, Control, WDGS, and DDGS were all significantly more yellow than the HP-DDGS treatment. At 9 d of aging with 7 d of retail display, steaks from Bran and DDGS had greater yellowness values ($P < 0.05$) compared to HP-DDGS. There were no differences ($P > 0.05$) in b* values between dietary treatments at 23 d of aging and 7 d of retail display.

Table 1. Discoloration (%) of strip loin steaks (*Longissimus lumborum*) from steers fed either a corn diet, 40% high protein dry distillers grains plus solubles (HP-DDGS), 40% dry distillers grains plus solubles (DDGS), 40% wet distillers grains plus solubles (WDGS), or 40% bran plus solubles (Bran) with 2, 9, and 23 d of aging at 5, 6, and 7 d of retail display.

	Aging period								
	2			9			23		
Days in retail display	5	6	7	5	6	7	5	6	7
Dietary treatments									
Corn	0.29^{a}	0.72^{a}	1.59^{b}	0.13^{a}	0.68^{b}	1.68^{b}	3.13^{a}	15.75^{c}	38.85^{d}
WDGS	0.47^{a}	1.77^{a}	4.74^{b}	0.31^{a}	1.64^{ab}	5.67^{b}	6.02^{a}	34.45^{bc}	63.63^{bc}
Bran	0.07^{a}	1.06^{a}	2.89^{b}	0.87^{a}	3.26^{ab}	6.79^{b}	18.98^{a}	46.24^{ab}	68.30^{ab}
DDGS	0.59^{a}	1.92^{a}	4.82^{b}	0.15^{a}	1.92^{ab}	4.83^{b}	13.88^{a}	45.05^{ab}	74.19^{ab}
HP-DDGS	0.44^{a}	4.86^{a}	15.32^{a}	1.74^{a}	7.67^{a}	19.88^{a}	16.30^{a}	64.31^{a}	85.79^{a}

$^{a-d}$ Means in the same column with different superscripts are different ($P<0.05$)

Table 2. Lipid oxidation value (TBARS; mg malonaldehyde/kg of meat) of strip loin steaks (*Longissimus lumborum*) from steers fed either a corn diet, 40% high protein dry distillers grains plus solubles (HP-DDGS), 40% dry distillers grains plus solubles (DDGS), 40% wet distillers grains plus solubles (WDGS), or 40% bran plus solubles (Bran) with 0, 4, and 7 d retail display.

	Days in retail display		
Dietary treatment	0	4	7
Corn	0.67^{a}	1.45^{a}	2.38^{c}
WDGS	0.77^{a}	2.04^{a}	4.27^{ab}
Bran	0.73^{a}	2.08^{a}	3.86^{b}
DDGS	0.85^{a}	1.64^{a}	3.19^{bc}
HP-DDGS	0.80^{a}	2.40^{a}	5.15^{a}

$^{a-c}$ Means in the same column with different superscripts are different ($P<0.05$)

After 7 d of retail display following 2 and 9 d of aging, panelists judged the steaks from cattle fed HP-DDGS had more discoloration ($P < 0.05$) than all other treatments, which were similar. Following 23 d of aging, steaks from cattle fed HP-DDGS had the most discoloration and all treatments except WDGS were more discolored than Control ($P < 0.05$) after 6 and 7 d of retail display.

A retail by treatment interaction ($P < 0.001$) was observed for lipid oxidation. After 7 d of retail display, steaks from cattle fed HP-DDGS had greater TBARS values ($P < 0.05$) than all other treatments except steaks from WDGS-fed cattle. There were no differences in lipid oxidation between steaks from cattle fed WDGS, Bran, and DDGS. The lowest concentration of TBARS occurred in steaks from cattle fed Control, which were different (P < 0.05) from all steaks except those from the DDGS treatment.

As expected, no differences were observed among treatments for sarcomere length ($P = 0.07$), fat ($P = 0.51$), moisture ($P = 0.71$), or ash ($P = 0.74$). An aging effect was found for pH ($P < 0.0001$). However, the difference in values were of little practical significance (5.48 at 2 d, 5.44 at 9 d, 5.49 at 23 d, respectively). As aging increased, there was a significant increase of free calcium levels in the meat ($P < 0.0001$) (2 d:60.06 µM; 9 d: 66.27 µM; 23 d: 67.82 µM). Although there were no statistical differences ($P = 0.07$) in free calcium content between dietary treatments, there was a tendency where steaks from WDGS had the greatest free calcium levels and Control steaks the lowest (68.15 µM, and 62.05 µM, respectively).

Conclusions

Although the feeding of high protein distillers grain to cattle did not alter the tenderness of the muscle, there could be significant economic ramifications due to the increase in lipid oxidation and discoloration under retail display conditions which resulted in shorter shelf life.

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Impact of Dietary Fat Source on Beef Tenderness

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Nicolas J. Herrera
Kellen B. Hart
Chris R. Calkins

Summary with Implications

Steers were finished on either a corn control, 40% full-fat modified distillers grains plus solubles, 40% de-oiled modified distillers grains plus solubles, or 38% de-oiled modified distillers grains plus solubles plus 2% corn oil diet to evaluate the effects of dietary fat source on the mechanism of beef tenderization . Feeding modified distillers grains plus solubles increased polyunsaturated fatty acid content in the sarcoplasmic reticulum membrane and increased free Ca^{2+} concentration early postmortem. Steaks from cattle fed de-oiled modified distillers grains and de-oiled modified distillers grains plus corn oil were more tender at 2 d of aging when compared to corn control diet. These data indicate that feeding modified distillers grains plus solubles to cattle has the potential to increase beef tenderness early postmortem in comparison to corn diets.

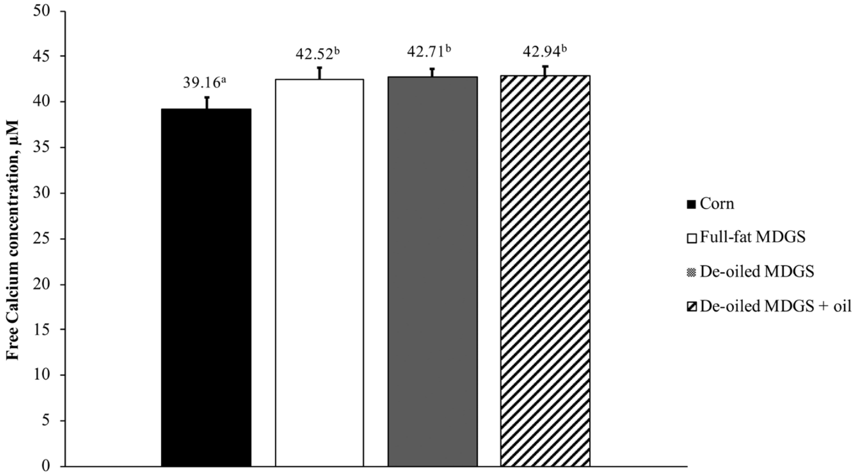

Figure 1. Free calcium concentration of strip loins steaks aged for 2 d from steers fed either a corn diet, 40% Full-fat modified distillers grains plus solubles (MDGS), 40% De-oiled MDGS or 38% De-oiled MDGS plus 2% corn oil. $^{a-b}$ Different superscripts indicate differences ($P = 0.05$).

Introduction

Research evaluating the impact of distillers grains on beef tenderness has provided conflicting results. Recent studies conducted at the University of Nebraska suggest that beef from steers fed wet distillers grains plus solubles can be more tender earlier postmortem than beef from steers fed the corn control diet. The hypothesis is that elevated concentrations of polyunsaturated fatty acids (PUFA) in the sarcoplasmic reticulum (SR) membrane may cause the SR membrane to rapidly lose integrity due to increased oxidation potential, leading to early postmortem release of previously sequestered Ca^{2+}. This released free Ca^{2+} potentially could interact with calpains and accelerate early postmortem protein degradation, making meat more tender. Therefore, this study was conducted to determine the effect of feeding different dietary fat sources with modified distillers grains plus solubles (MDGS) on the beef tenderization mechanism.

Procedure

A total of 256 steers were allocated in 32 pens (8 hd/pen) and fed for 134 d on either a corn control, 40% full-fat MDGS (dry matter basis), 40% de-oiled MDGS, or 38% de-oiled MDGS plus 2% corn oil diet. Strip loins from 24 USDA Choice carcasses (3 hd/pen) were randomly selected within each dietary treatment and strip loins from both sides were collected. Then, both loins per carcass were divided in half, and each of the four loin sections were randomly assigned to one of the four aging periods (2, 9, 16, or 23 d). On d 2 of aging, loin sections were trimmed of subcutaneous fat, and fabricated into two steaks and utilized to determine sarcomere length, troponin-T degradation, fatty acid profile of the SR membrane, free Ca^{2+} concentration, and tenderness [1 steak for tenderness (1 in thickness) and 1 steak (0.5 in thickness) for all other analysis]. Loin sections aged for 9, 16, and 23 d were analyzed only for tenderness. Tenderness was measured via Warner-Bratzler shear force (WBSF) method, sarcomere length was measured via laser diffraction, SR membrane fatty acids were analyzed via gas chromatography, free Ca^{2+}concentration was analyzed via inductively coupled plasma spectroscopy, and troponin-T degradation was analyzed via immunoblotting. Tenderness data were analyzed as a split-plot design with dietary fat source as the whole-plot and aging period as the split-plot. All other variables evaluated at d 2 postmortem were analyzed as a completely randomized design. Pen was considered the experimental unit and data were analyzed using the PROC GLIMMIX procedure of SAS. All means were separated with the LS MEANS and DIFF functions ($\alpha = 0.05$). Tendencies were considered at $P < 0.10$.

Results

Results for the SR membrane fatty acid profile are presented in Table 1. Feeding

Table 1. Fatty acid profile (%) of sarcoplasmic reticulum membrane from strip loins from steers fed either a corn diet, 40% Full-fat modified distillers grains plus solubles (MDGS), 40% De-oiled MDGS or 38% De-oiled MDGS plus 2% corn oil.

	Dietary Treatment					
Fatty Acids, %	Corn	Full-fat MDGS	De-oiled MDGS	De-oiled MDGS + oil	SEM	*P*-value
C14:0	0.64	0.59	0.55	0.71	0.24	0.92
C15:0	0.52	0.54	0.29	0.22	0.17	0.30
C15:1	2.15	1.78	2.02	1.68	0.20	0.33
C16:0	17.73	17.84	17.23	17.89	1.01	0.97
C16:1	1.11	1.04	1.10	1.09	0.13	0.93
C17:0	0.85	0.65	0.63	0.62	0.10	0.16
C17:1	0.70	0.72	0.44	0.52	0.12	0.39
C18:0	14.87	12.97	13.22	13.84	0.61	0.20
C18:1	22.70	21.40	21.31	21.91	1.14	0.80
C18:1V	2.43^{a}	1.91^{b}	2.02^{b}	2.10^{ab}	0.10	< 0.01
C18:2	17.63^{b}	24.51^{a}	23.37^{a}	23.03^{a}	1.27	< 0.01
C18:3	0.67	0.41	0.66	0.69	0.16	0.61
C20:3	2.14	1.68	1.85	1.77	0.18	0.28
C20:4	8.37	8.04	8.20	7.35	0.60	0.71
C22:4	0.92	0.71	0.94	0.85	0.10	0.24
C22:5	1.81	1.55	1.59	1.62	0.13	0.77
SFA	35.18	32.09	31.95	33.48	1.45	0.62
MUFA	28.97	27.45	27.57	28.28	1.19	0.41
PUFA	31.26^{b}	36.85^{a}	36.46^{a}	37.25^{a}	1.70	0.06
Fat	6.67	6.78	6.84	7.55	0.33	0.34

Note: SFA = saturated fatty acids, MUFA = monounsaturated fatty acids, PUFA = polyunsaturated fatty acids, and Fat = fat content of the meat (%). $^{a\text{-}b}$ Different superscripts within the same row indicate differences ($P < 0.05$). P values between 0.05 and 0.10 were considered as trends.

MDGS decreased ($P < 0.05$) concentrations of 18:1V, increased ($P < 0.05$) concentrations of linoleic acid (18:2) and tended to increase ($P = 0.06$) total PUFA in the SR membrane. The increase in PUFA content of the SR membrane supports the hypothesis that feeding MDGS may alter SR membrane integrity and thus accelerate free Ca^{2+} release.

Free Ca^{2+} values of dietary treatments are presented in Figure 1. Dietary fat source influenced free Ca^{2+} concentration of beef. Steaks from cattle fed MDGS had greater free Ca^{2+} concentrations than steaks from cattle fed corn at d 2 postmortem ($P = 0.05$). Calcium has a major role in meat tenderization as the calpain system requires the presence of Ca^{2+} to be activated. The earlier Ca^{2+} release observed at d 2 postmortem in this project for all MDGS treatments compared to the corn diet supports the hypothesis that feeding high concentrations of distillers grains to cattle could increase free Ca^{2+} available early-postmortem, which could result in improved tenderness.

No differences in sarcomere length among dietary treatments were observed at 2 days postmortem ($P = 0.92$). The average sarcomere length of strip loins from cattle fed corn-only, de-oiled MDGS, de-oiled MDGS plus corn oil and full-fat MDGS were 1.77, 1.76, 1.75 and 1.76 μm, respectively. Sarcomere length has long been recognized as a factor influencing meat tenderness. Relevant changes in sarcomere length begin to occur early postmortem when sarcomeres contract as the muscle goes into rigor. If Ca^{2+} is released when adenosine triphosphate (ATP) is still available, muscle contraction can occur, resulting in detrimental effects on meat tenderness. However, sarcomere length was not compromised in this project, indicating that the earlier release of calcium found in all MDGS treatments likely occurred after the depletion of ATP reserves (completion of rigor mortis).

No differences in troponin-T degradation were found between dietary treatments at 2 d postmortem ($P = 0.60$). The average troponin-T degradation of strip loins from cattle fed corn-only, de-oiled MDGS, de-oiled MDGS plus corn oil and full-fat MDGS were 20.44, 23.85, 22.24 and 24.72%, respectively. It seems that the relationship between troponin-T degradation and improvement in beef tenderness is not linear and that some minimum threshold of degradation is necessary for proteolysis to have any measurable effect on meat tenderness.

Dietary treatment tended to affect WBSF at d 2 postmortem ($P = 0.08$). Compared to steaks from steers fed corn, steaks from steers fed de-oiled MDGS and de-oiled MDGS plus corn oil had lower Warner-Bratzler shear force ($P = 0.03$) at d 2 of aging (Figure 2). Extending aging beyond 2 d mitigated the tenderness effects, as there were no significant differences in tenderness among dietary treatments on samples aged for 9 ($P = 0.38$), 16 ($P = 0.73$) or 23 d ($P = 0.96$). The results from this study suggest that feeding de-oiled MDGS and de-oiled MDGS plus corn oil to cattle has the potential to increase early postmortem tenderness, which likely was the result of increased total 18:2 and PUFA in the SR membrane and earlier free Ca^{2+} release.

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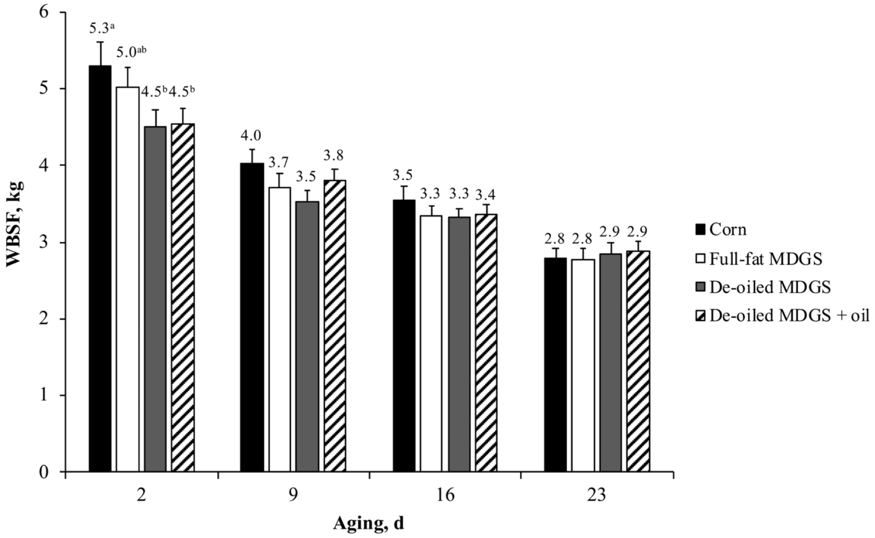

Figure 2. Warner-Bratzler shear force (WBSF) values (kg) of strip loins steaks from steers fed either a corn diet, 40% Full-fat modified distillers grains plus solubles (MDGS), 40% De-oiled MDGS or 38% De-oiled MDGS plus 2% corn oil aged for 2, 9, 16 or 23 days. $^{a\text{-}b}$ Different superscripts indicate differences ($P < 0.05$).

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 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)

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Quality Assurance
Research and Development
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