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Growing System Effects on Silage Type Selection for the Finishing Phase of Beef Steers: Feedlot Growth Performance, Carcass Characteristics, Nutrient Digestibility, and Feeding Behavior

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Abstract

The effects of beef cattle growing systems on type of silage during the finishing phase were assessed based on growth performance, carcass characteristics, digestibility, and feeding behavior. Steers (n = 128; BW = 394 ± 21 kg) were used in a 2 × 2 factorial treatment arrangement: a) growing system (Grazing [forage sorghum bmr-6 AF7401]; or Bunk-fed [65% concentrate diet]); and b) finishing diet silage source (Corn silage [BH8895]; or Sorghum silage [bmr-6 AF7401]) 20% inclusion (DM basis). Pen (n = 8 per treatment) was the experimental unit during the finishing phase and a split plot experimental design was used. Only descriptive data was recorded during the growing system phase. No interactions (growing system × finishing phase silage type) were observed (P > 0.16). Steers that grazed had greater ADG (P < 0.01), DMI (P < 0.01), and G:F (P < 0.01) during the finishing phase, than bunk-fed steers. Greater HCW (P < 0.01), less DP (P < 0.01), and less 12th-rib fat (P < 0.01) were observed for steers grown on the forage sorghum grazing system than Bunk-fed steers during growing phase. Regardless of growing system, steers fed the corn silage-based finishing diet had less DMI (P < 0.01), greater G:F (P < 0.01), and tended (P = 0.06) to have greater ADG during the finishing phase than steers fed the sorghum silage-based finishing diet. The corn silage-based finishing diet had greater digestibility of nutrients (P < 0.01) than the sorghum silage-based finishing diet, except by fiber, which was not different (P ≥ 0.12) among treatments. Sorghum grazing during growing phase positively affected growth performance during the finishing phase. Replacing corn silage with sorghum silage in beef finishing diets at inclusions used in current study requires diet energy adjustments.

Introduction

The Texas High Plains and surrounding semi-arid regions have been overwhelmed with periods of long-standing drought, and more frequent and intense periods of drought-like conditions [1]. Crop production in this region has used supplemental irrigation with water pumped from the Ogallala aquifer at rates that have exceeded recharge for many years [2]. Water from the Ogallala will most likely not be available in the future to sustain irrigated agriculture in this region, therefore adoption of water conservation strategies is imperative [3]. Water availability for irrigation in some portions of these regions is declining to critically low levels. From 2006 to 2016 in the 15 counties surrounding the city of Lubbock Texas in the Texas Panhandle, the water level in the Ogallala aquifer declined, on average, 283 mm per year [4]. Compared to other cereal crops, sorghum can play a major role in increasing the resilience and sustainability of agricultural systems in arid regions because sorghum's high water-use efficiency [5]. However, due to the diversity of forage sorghum varieties, more work is needed to understand the nutritive and agronomic properties of newer varieties within the climatic conditions of these regions. The Texas High Plains is an important region for feedlot and dairy production, and roughage is a critical dietary ingredient used to optimize animal performance. Because of its bulk, transportation and handling of roughages is more expensive than other feed commodities, these, operations rely on locally grown roughage sources. Historically, dairies and feedlots in these regions have relied on corn silage; however, newer forage sorghum varieties may have greater nutrient digestibility and less lignin content than traditional varieties. More information about the nutritive properties of new sorghum varieties is critical to better understand how these forages can be fed to high-producing ruminants, and how their feeding value compares with corn silage. Therefore, the objectives of this study were to determine the effects of using sorghum (bmr-6 AF7401) and corn (BH8895) silages in finishing diets of steers originated from growing systems of forage sorghum grazing or bunk-fed 65% concentrate diet on feedlot growth performance, carcass characteristics, nutrient digestibility, and feeding behavior.

Materials and Methods

All procedures involving live animals were approved by the Texas Tech University Institutional Animal Care and Use Committee (Protocol # 14023-03).

Dietary treatments and experimental design

A 2 × 2 factorial treatment arrangement was used, consisting of two growing systems (bunk-fed or grazing), and two dietary treatments during the finishing phase (silage types). Data were analyzed as a split plot design. During growing phase, animals were commingling within each system group. Therefore, only descriptive data were recorded during growing phase. After growing phase was completed, each respective group of animals (bunk-fed or grazing) was then assorted into experimental units (further described) for the finishing phase. During the finishing phase, treatments consisted of: A) corn silage-based finishing diet; or B) *Sorghum silage*-based finishing diet. Each forage source was included at 20% (DM basis),

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Table 1: Dietary ingredient inclusion and analyzed nutritional composition of beef steers finishing diets containing corn silage or sorghum silage.

Item	Finisher diet[1]	
	Corn	Sorghum
Ingredient Inclusion, % DM		
Steam-flaked corn	55.57	55.68
WCGF (Sweet bran)	15	15
Yellow grease	3.5	3.5
Limestone	1.86	1.78
Urea	0.87	0.84
Mineral supplement[2]	2	2
Cottonseed meal	1.2	1.2
Corn silage (BH8895)	20	-
Sorghum silage (bmr-6 AF7401)	-	20
Analyzed Nutritional Composition, DM basis[3]		
Starch, %	50.9	47.9
Crude protein, %	13.4	14.1
Neutral detergent fiber, %	17.4	20
Acid detergent fiber, %	7.9	10.6
Ether extract, %	6.7	6.36
Ca, %	0.77	0.75
P, %	0.38	0.38
K, %	0.74	0.85
Mg, %	0.2	0.23
S, %	0.158	0.162

[1]**Corn:** 20% (DM basis) inclusion of corn silage (BH8895); Sorghum: 20% (DM basis) inclusion of sorghum silage (bmr-6 AF7401).
[2]**Supplement contained (DM basis):** Carrier (cottonseed meal), 67.7538%; antioxidant (Endox, Kemin Industries, Des Moines, IA), 0.5%; urea, 3.76%; potassium chloride, 10%; sodium chloride, 15%; cobalt carbonate, 0.0022%; copper sulfate, 0.1965%; Iron sulfate, 0.0833%; ethylenediamine dihydroiodide, 0.0031%; manganous oxide, 0.167%; selenium premix (0.2% Se), 0.125%; zinc sulfate, 0.9859%; Vitamin A (1,000,000 IU/g), 0.0099%; Vitamin E (500 IU/g), 0.157%; and provided (dietary) 30 mg/kg of monensin (0.75% Rumensin-90 in suppl., Elanco Animal Health, Indianapolis, IN) and 9 mg/kg of tylosin (0.5063% Tylan-40 in suppl., Elanco Animal Health).
[3]Analyzed composition from a commercial laboratory (Servi-Tech Laboratories, Amarillo, TX).

and diets were balanced for CP (Table 1). Pen (4 steers per pen) was the experimental unit, with one pen per treatment within each BW block, resulting in 8 pens per treatment and a total of 32 experimental units. Ingredients and analyzed nutritional composition of the two finishing diets are provided in Table 2. Each treatment diet contained the same mineral and vitamin supplement to meet or exceed NRC (1996) requirements, monensin (30 mg/kg DM basis: Elanco Animal Health, Greenfield, IN.), and tylosin (9 mg/kg DM basis; Elanco Animal Health). The percentage of premix included in the diets was pre-determined by assuming an average daily DMI of 9.07 kg per steer.

Sorghum pasture and bunk-fed cattle management during growing phase

Sorghum (bmr-6 AF7401; Advanta Seeds US, Irving, TX) used for grazing was planted on 32 ha, at the Texas Tech University Research Center (Idalou, TX; 33°45N, 101°47W; 993 m asl). The area contained sub-surface drip irrigation located 46 cm below the soil surface, with 1 m spacing between drip tapes. Sorghum was sown directly above the drip-tapes, at the rate of 5.61 kg per ha, in order to generate approximately 200,000 plants per ha. Sowing was performed between May 23 and 30 of 2014. Because of rainfall before planting completion, 24 ha were planted on May 23 and the remaining 8 ha on May 30. As cattle in growing phase grazed paddocks as a group, no special grazing management or division was performed to accommodate differences in planting date. The area was equally divided into 3 paddocks using electric fence. Sorghum was allowed to grow for 47 d after sowing before animals were placed on the area on July 9.

Two groups of cattle arrived at the Texas Tech University Burnett Center, and were part of either a grazing or bunk-fed during the phase. For the forage sorghum grazing system, commercial Angus steers, (n = 75; BW = 292 ± 28 kg) arrived at the Texas Tech University Burnett Center on July 9. At arrival, steers were individually weighed (Silencer Chute, Moly Manufacturing, Lorraine, KS; mounted on Avery Weigh-Tronix load cells, Fairmount, MN; readability ± 0.45 kg), and implanted with Revalor-G (40 mg trenbolone acetate, 8 mg estradiol; Merck Animal Health, Summit, NJ). Steers were vaccinated for Bovine Rhinotracheitis, Parainfluenza3, Bovine Respiratory Syncytial Virus, Bovine Virus Diarrhea type I and II (Bovi-Shield Gold 5; Zoetis Animal Health, Florham Park, NJ), *Clostridium chauvoei, Clostridium septicum, Clostridium novyi, Clostridium sordellii, Clostridium perfringens* types C & D (Ultrabac 7; Zoetis Animal Health), treated

Table 2: Effects of growing system (bunk-fed or Grazing) on finishing phase silage type (Corn or Sorghum) of beef steers growth performance.

Item	Bunk-fed		Grazing		SEM[1]	System	*P* - value[2]	
	Corn	Sorghum	Corn	Sorghum			Forage	S × F
Initial BW, kg	396	395	391	391	7.4	< 0.01	0.45	0.3
FsBW, kg[3]	606	605	667	655	8.3	< 0.01	0.46	0.46
Adj.FsBW, kg[4]	611	607	666	648	8.5	< 0.01	0.2	0.44
DMI, kg per d								
d 0 to 56	8.4	9.3	10.6	10.8	0.22	< 0.01	< 0.01	0.07
d 56 to 112	8.7	9.8	11.5	12.1	0.24	< 0.01	< 0.01	0.16
d 0 to end	8.6	9.7	11.1	11.4	0.2	< 0.01	< 0.01	0.06
Final 28 d[5]	8.8	9.9	10.9	11.4	0.28	< 0.01	< 0.01	0.2
ADG, kg								
d 0 to 56	1.66	1.58	2.34	2.26	0.065	< 0.01	0.26	0.94
d 56 to 112	1.39	1.5	1.9	1.76	0.068	< 0.01	0.78	0.06
d 0 to end	1.39	1.39	1.85	1.76	0.04	< 0.01	0.29	0.23
Adj. d 0 to end[6]	1.43	1.41	1.84	1.7	0.041	< 0.01	0.06	0.19
Final 28 d[5]	1.64	1.69	1.85	1.82	0.119	0.16	0.94	0.72
G:F								
d 0 to 56	0.195	0.169	0.222	0.21	0.0056	< 0.01	< 0.01	0.16
d 56 to 112	0.161	0.152	0.166	0.146	0.0045	0.88	< 0.01	0.17
d 0 to end	0.161	0.144	0.167	0.154	0.0025	< 0.01	< 0.01	0.5
Adj. d 0 to end[6]	0.166	0.145	0.166	0.15	0.0029	0.4	< 0.01	0.54
Final 28 d[5]	0.186	0.171	0.169	0.159	0.0099	0.15	0.21	0.77

[1]Standard error of the mean, n/treatment = 8.
[2]System (growing phase by grazing bmr-6 AF7401; or bunk-fed growing diet); Forage (dietary forage source in finishing phase as corn silage BH8895 or sorghum silage bmr-6 AF7401); and S × F (interaction system × forage).
[3]Final shrunk body weight. 4% shrink was applied to final live body weight.
[4]Carcass-adjusted FsBW calculated from hot carcass weight divided by the average dressing percent within system (61.7 and 62.5% for grazing and bunk fed, respectively) and adjusted by a 4% shrink.
[5]Ractopamine hydrochloride 300 mg per steer daily fed for the last 28 d (Optaflexx; Elanco Animal Health). 4% shrink was applied to live body weights.
[6]Carcass-adjusted ADG and G:F from carcass-adjusted final shrunk BW, initial BW, and days on feed.

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Table 3: Dietary ingredients and analyzed nutritional composition of growing and step-up diets fed to steers.

Item	Step-up 1[1]	Step-up 2[4]		Step-up 3[4]	
		Corn	Sorghum	Corn	Sorghum
Ingredient Inclusion, % DM					
Steam-flaked corn	38.72	44.48	44.55	50.79	50.89
WCGF[2]	20	17.5	17.5	15	15
Alfalfa hay	23.35	12	12	6	6
Cottonseed hulls	11.65	8	8	4	4
Yellow grease	3	3	3	3.5	3.5
Limestone	0.9	1.24	1.19	1.86	1.78
Urea	0.38	0.58	0.56	0.65	0.63
Supplement[3]	2	2	2	2	2
Cottonseed meal	-	1.2	1.2	1.2	1.2
Corn silage	-	10	-	15	-
Sorghum silage	-	-	10	-	15
Nutritional Composition, DM basis					
Starch[5], %	28.7	37.9	36.4	45.3	43.3
Crude protein, %	14.9	16.3	15.4	14.3	14.6
NDF, %	33.2	23.6	24.6	20.4	19.5
Ether extract, %	6.23	5.1	5.6	6.1	7.2
Ca[5], %	0.69	0.83	0.79	0.87	1.02
P[5], %	0.39	0.4	0.37	0.41	0.39
K[5], %	1.01	1.24	1.25	1	1.07
NEm[6], Mcal/kg	1.87	2.09	2.07	2.18	2.18
NEg[6], Mcal/kg	1.22	1.43	1.41	1.5	1.5

[1]Diet used for bunk fed during growing strategy and for the steers originated from grazing system 14 d before finishing.
[2]Sweet Bran® (Cargill Corn Milling, Blair, NE).
[3]Supplement contained (DM basis): Carrier (cottonseed meal), 67.7538%; antioxidant (Endox, Kemin Industries, Des Moines, IA) 0.5%; urea, 3.76%; potassium chloride, 10%; sodium chloride, 15%; cobalt carbonate, 0.0022%; copper sulfate, 0.1965%; Iron sulfate, 0.0833%; ethylenediamine dihydroiodide, 0.0031%; manganous oxide, 0.167%; selenium premix (0.2% Se), 0.125%; zinc sulfate, 0.9859%; Vitamin A (1,000,000 IU/g), 0.0099%; Vitamin E (500 IU/g), 0.157%; and provided (dietary) 30 mg/kg of monensin (0.75% Rumensin-90 in suppl., Elanco Animal Health, Indianapolis, IN) and 9 mg/kg of tylosin (0.5063% Tylan-40 in suppl., Elanco Animal Health).
[4]Adaptation steps 2 and 3 contained the experimental silages and were included in the finishing study.
[5]Commercial lab.
[6]Calculated composition based on regularly analyzed individual ingredients used in the Burnett Center Research Station.

for internal parasites (Safe-Guard, Merck Animal Health, Summit, NJ), and external/internal parasites (Dectomax, Zoetis Animal Health, Florham Park, NJ). Steers were housed in soil-surfaced pens with 8 to 10 steers per pen overnight, with access to long-stem hay and water. The following morning, steers were moved to single forage sorghum pasture (bmr-6 AF7401) for the grazing period (10.67 ha). During the grazing period, steers had free access to forage-sorghum pasture and mineral supplement (Forage Pro RU1600 Wheat Pasture Supplement; contained 1,600 mg/kg of monensin; Hi-Pro Feeds, Friona, TX).

Steers grazed each paddock (10.67 ha) as a group, for approximately 37 d. Animals did not return to grazed paddocks. Steers were removed from the forage-sorghum pasture on October 23, 2014 (111 d) and limit fed a (1.2% BW) 65% concentrate receiving diet for 5 d before the final grazing individual BW was obtained (October 28, 2014). This weight was used for sorting to the respective finishing diet treatments.

For steers enrolled in the 65% concentrate bunk-fed growing system, commercial Angus steers (n = 77; initial BW = 236 ± 18 kg) arrived at the Texas Tech University Burnett Center on July 28. Upon arrival, steers were processed as follows: a) individually weighted (the same scale and method previously described); b) implanted with Ralgro (36 mg Zeranol, Merck Animal Health); c) vaccinated and treated for external/internal parasites as previously described. After arrival, steers were housed in soil-surfaced pens (8 to 10 steers per pen), and fed a 65% concentrate receiving diet for 92 d. The growing diet ingredients and analyzed nutritional composition are presented in Table 3.

Cattle management during finishing phase

On October 28, 2014, an unshrunk sorting BW from both grazing and bunk-fed steers was obtained; 64 steers from each management system (total n = 128) were selected for enrollment into the finishing phase based on BW. Enrolled steers were ranked by ascending BW, assigned to BW block (n = 8), with 2 pens of steers from each of the previously described management systems represented in each block, and returned to soil-surfaced pens. On November 11, initial BW measurements were recorded and all steers were implanted with Revalor-XS (200 mg of TBA and 40 mg estradiol, Merck Animal Health). Steers within each block were randomly assigned to pens (4 steers per pen). Pens (experimental unit; concrete, partially slotted floor; 3 m wide × 6 m deep; linear bunk space = 2.5 m) within each block and management system were assigned randomly to 1 of 2 dietary treatments. Thus, treatments were replicated in 32 pens (8 pens per treatment). Immediately after initial BW measurement, the step-up-2 diets were fed (7 d), followed by step-up-3 diet (7 d), until the finisher diets were fed (Table 1).

Diet sampling, feed delivery, and weighing procedures

Feed bunks were inspected visually at 0700 to 0730 h daily to estimate the quantity of residual feed for each pen, and were managed

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Table 4: Effects of growing system (bunk-fed or Grazing) on finishing phase silage type (Corn or Sorghum) of beef steers carcass characteristics.

Item	Bunk-fed		Grazing		SEM[1]	System	P – value[2]	
	Corn	Sorghum	Corn	Sorghum			Forage	S × F
HCW, kg[3]	396	393	431	419	5.5	< 0.01	0.2	0.44
Dressing percent[4]	62.7	62.3	62	61.4	0.29	< 0.01	0.03	0.85
Fat thickness, mm	18	17.8	15.7	13.3	0.83	< 0.01	0.14	0.21
LM area, cm[5]	93.3	91.3	93.6	91.9	2.08	0.8	0.64	0.95
Marbling score[6]	47.8	46.1	47.9	46.5	1.75	0.88	0.38	0.96
KPH, %	2.16	2.03	2.15	2.08	0.053	0.66	0.4	0.56
Yield grade	3.4	3.42	3.44	3.18	0.143	0.44	0.39	0.28
Quality grade[7]								
Premium choice, %	34.4	28.3	32.1	35.5	9.78	0.87	0.81	0.67
Choice, %	34.4	50	45.2	46.8	8.94	0.73	0.5	0.57
Upper choice, %	72	78.2	80.7	81.3	8.33	0.45	0.68	0.75
Select, %	28	21.8	19.3	18.7	8.33	0.45	0.68	0.75
Total liver condemnations[8]								
Total, %	9.4	12.5	6.5	15.6	6.42	0.92	0.47	0.68

[1]Standard error of the mean, n/treatment = 8.
[2]System (growing phase by grazing bmr-6 AF7401; or bunk-fed growing diet); Forage (dietary forage source in finishing phase as corn silage BH8895 or sorghum silage bmr-6 AF7401); and S × F (interaction system × forage).
[3]Hot carcass weight, kg.
[4]Dressing percent was calculated using non-shrunk BW/HCW.
[5]Longissimus muscle area, at 12th rib.
[6]30 = slight; 40 = small; 50 = modest; 60 = moderate; 70 = slightly abundant.
[7]Quality grade, determined by USDA personnel. "Premium Choice" and "Choice" are included on "Upper Choice". Only 2 carcasses graded USDA Prime (both carcasses came from steers fed corn silage in the fishing phase diet, whereas they originated from different growing systems.
[8]One liver scored an abscess "A+". It came from a steer fed sorghum silage originated from the sorghum grazing growing system. Seven livers scored abscess "A", of which 4 were livers of steers fed sorghum silage coming from grazing growing system, 2 from steers fed corn silage that came from the bunk-fed growing system, and 1 from a steer fed sorghum silage that came from the bunk-fed growing system.

such that only trace amounts of feed (less than 200 g) remained before the next feeding. A 1.27-m^3-capacity paddle mixer (Marion Mixers Inc. Marion, IA) was used to mix diets and a drag-chain conveyor was used to move feed from the mixer to tractor-pulled mixer/delivery unit (Roto-Mix 84-8, Roto-Mix, Dodge City, KS; scale readability of ± 0.45 kg) for delivery of feed to the bunk. For each diet, all ingredients were milled in the batching system, except for wet corn gluten feed (WCGF, Sweet Bran-Cargill, Blair, NE) and silages, which were directly added to the mixer unit for each specific diet, and each complete diet was mixed thoroughly for approximately 10 minutes before delivery.

Diets were sampled each week immediately after bunk delivery from each of the 16 pens per finishing treatment, composited by dietary treatment, and composited within 28-d periods. Dietary composites were analyzed at the end of the study by Servi-Tech Laboratories (Amarillo, TX) for CP, NDF, ADF, ether extract, starch, Ca, P, K, and S. Sub-samples from dietary weekly composites were used to determine DM content (100 °C; forced-air oven; 24 h) and assess DMI of pens. Except for silages (samples obtained weekly) dietary ingredients were sampled every other week for determination of DM (100 °C; forced-air oven; 24 h). Ractopamine hydrochloride (Optaflexx; Elanco Animal Health) was administered the final 28-d of the finishing period at 300 mg per steer daily.

Initial individual BW was taken on d 0. Throughout the finishing period, interim unshrunk pen weights were collected every 28 d using a platform scale (readability ± 2.3 kg). Individual BW were taken before the β-agonist feeding administration and before shipment to slaughter. Scales used to weigh steers were validated with certified weights (454 and 907 kg for individual and platform ones, respectively).

Slaughter and carcass measurements

Steers within respective BW blocks were sent to a commercial slaughter facility on 3 dates. Blocks 6, 7 and 8 were slaughtered on March 23 of 2015, with 132 d on feed (DOF); blocks 3, 4 and 5 were harvested on April 6, with 146 DOF; and blocks 1 and 2, were harvested on May 4, with 174 DOF. Blocks were shipped for slaughter upon visual appraisal, aiming to have approximately 65% or greater animals in a given block with sufficient finish to grade USDA Choice. Steers were shipped the morning of each slaughter date, with an individual BW measurement obtained before shipping (animals were not fed). A 4% pencil shrink was used for determination of final BW. Steers were transported 220 km to a commercial slaughter facility (Tyson Fresh Meats Inc. Amarillo, TX). Carcass characteristics were evaluated 24 h after slaughter by trained personnel from the West Texas A&M University Carcass Data Research Center (Canyon, TX). Dressing percent was calculated by dividing the HCW by the unshrunk final BW. Carcass-adjusted final BW was calculated using HCW divided by the average dressing percent of steers from each growing system (62.5%, and 61.7% for bunk-fed and grazing steers, respectively) and adjusted by a 4% shrink. Carcass-adjusted final BW was used to calculate carcass-adjusted ADG using unshrunk limited-fed initial BW and DOF; carcass-adjusted ADG divided by average DMI for the experiment was used to calculate carcass-adjusted G:F.

Silages

Silages used in the current study were stored in plastic bag silos (3.35 m of diameter) prepared within 6 h after being chopped. Sorghum forage (bmr-6 AF7401) was received at the Texas Tech

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Table 5: Effects of growing system (bunk-fed or Grazing) on finishing phase silage type (Corn or Sorghum) of beef steers total tract apparent digestibility and calculated dietary energy density.

Item	Bunk-fed		Grazing		SEM[1]	P - value[2]		
	Corn	Sorghum	Corn	Sorghum		System	Forage	S × F
DMI, kg per d[3]	7.87	8.7	10.98	11.16	0.229	< 0.01	0.03	0.15
Nutrient Apparent Digestibility, %								
DM	74.6	66.3	72.5	65.9	1.14	0.22	< 0.01	0.41
OM	76.2	68.2	74	67.9	1.11	0.23	< 0.01	0.35
NDF	28.5	24.1	24.2	23.8	2.99	0.42	0.39	0.46
ADF	30	24.3	26.3	23.3	2.87	0.37	0.11	0.6
Hemicellulose	27.5	23.9	22.8	24.2	3.15	0.46	0.71	0.4
Starch	98.7	91.7	99	91	0.52	0.66	< 0.01	0.36
Crude protein	69.7	62.8	66.9	62.8	1.49	0.25	< 0.01	0.27
Ether extract	93.1	90.7	91.9	90.8	0.56	0.29	< 0.01	0.26
Calculated dietary energy value, Mcal/kg[4]								
NEm	2.14^{a}	1.94^{c}	2.03^{b}	1.92^{c}	0.017	< 0.01	< 0.01	0.01
NEg	1.47^{a}	1.30^{c}	1.37^{b}	1.27^{c}	0.016	< 0.01	< 0.01	0.02
ME	3.14^{a}	2.90^{c}	3.00^{b}	2.86^{c}	0.021	< 0.01	< 0.01	0.02

[1]Standard error of the mean, n/treatment = 8.
[2]System (growing phase by grazing bmr-6 AF7401; or bunk-fed growing diet); Forage (dietary forage source in finishing phase as corn silage BH8895 or sorghum silage bmr-6 AF7401); and S × F (interaction system × forage).
[3]DM intake during the 6-d digestion study (72 to 77 d on feed).
[4]Calculated from the growth performance data [10].

Table 6: Effects of growing system (bunk-fed or Grazing) on finishing phase silage type (Corn or Sorghum) of beef steers feeding behavior.

Item	Bunk-fed		Grazing		SEM[1]	P - value[2]		
	Corn	Sorghum	Corn	Sorghum		System	Forage	S × F
Time, min per d								
Rumination	245	269	260	276	12.2	0.18	0.02	0.64
Eating	105	123	111	129	6.8	0.38	0.01	0.99
Chewing[3]	350	392	371	405	14.2	0.07	< 0.01	0.69
Drinking	11	8	13	15	1.9	0.04	0.7	0.18
Active	63	65	60	55	5.7	0.25	0.79	0.53
Resting	1016	976	997	966	16.8	0.23	< 0.01	0.66
Rate, min per kg of DM								
Rumination	29	28	24	24	1.4	< 0.01	0.97	0.44
Eating	12	13	10	11	0.7	< 0.01	0.14	0.56
Chewing	41	41	34	36	1.7	< 0.01	0.3	0.27
Rate, min per kg of NDF								
Rumination	164	139	135	121	7.5	< 0.01	< 0.01	0.28
Eating	70	64	57	56	3.6	< 0.01	0.27	0.43
Chewing	234	203	193	177	9.1	< 0.01	< 0.01	0.13

[1]Standard error of the mean, n/treatment =8.
[2]System (growing phase by grazing bmr-6 AF7401; or bunk-fed growing diet); Forage (dietary forage source in finishing phase as corn silage BH8895 or sorghum silage bmr-6 AF7401); and S × F (interaction system × forage).
[3]Chewing activity calculated by adding time spent eating and time spent ruminating.

University Burnett Center from Earth, TX on October 15, 2014. Corn forage (BH8895) was obtained from a local commodity broker on October 22, 2014. Upon forage arrival, a set of samples were collected from each load (n = 8): 2 samples for freeze drying (237 mL plastic cups), 2 samples for DM determination (100 °C forced-air oven, 24 h), and 2 samples for determination of particle size (3.78 L bags). Average DM at arrival was 27.0%, and 39.6% for sorghum and corn forages, respectively. Two hundred g samples of the forages (2 samples per truck-load) were analyzed for intact grain proportions (14 and 38%, DM basis; for sorghum and corn forage, respectively).

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The observed reduced grain content of the *Sorghum forage* (measured by physical separation of intact grains) may not be suggestive of low starch content of the *Sorghum forage* upon harvesting, because part of the starch could possibly leave (liquid) sorghum grain berries due to forage manipulation. It is also important to note that the *sorghum forage* was harvested before completion of grain starch deposition, which resulted in harvesting forage at a low DM content (approximately 22%). Therefore, the *Sorghum forage* was wilted for approximately 24 h before ensiling. Wilting forages is known to increase ash content of the material ensiled, mainly because of soil contamination during forage collection. At ensiling, the ash (9.5 and 4.0%), lignin (4.2 and 2.1 %), CP (6.7 and 6.2%), NDF (37.8 and 32.5%), and starch (27.4 and 36.1%) content of sorghum and corn forages, respectively, were determined using freeze-dried samples of forage from each load. Sorting for average particle size quantification was completed as follows: samples of forage were separated using four particle size classes: greater than 11.1 mm, between 4.75 and 11.1 mm, between 1.18 and 4.75 mm, and below 1.18 mm into a sieve shaker (model SS-8R, Gilson Company, Inc. and Worthington, OH) after shaking for 30 s. Weight of each class was recorded for the calculation of the average particle size (DM basis). Average particle sizes observed were 6.5 and 8.1 mm, for sorghum and corn forage, respectively. Each morning, the amount of silage needed was unloaded from the silo bags using a skid-steer loader (Bobcat S450, Bobcat Company, West Fargo, ND) and transported (40 m) to the feed mill to be mixed with the other dietary ingredients.

Apparent total tract nutrient digestibility

Diet samples (approximately 1.2 kg) were collected once daily from the bunk from d 72 to 77 of the finishing phase immediately after delivery (approximately 0900 h). A subsample (approximately 200 g) of each diet sample was frozen at -20 °C for further analyses, and the remaining portion of the sample was used for determination of dietary DM (100 °C; forced-air oven; 24 h). Diet subsamples were composited by treatment at the end of the digestibility phase (5-d collection period). From d 73 to 78, feed refusals were weighed, and samples were collected. Ten % of the sample was frozen at -20 ˚C and DM was determined on the remaining portion of the sample by drying at 100 °C; in a forced-air oven for 24 h. Frozen subsamples were composited by pen following the digestion period for laboratory analyses. Spot fecal samples (approximately 250 g of fresh feces within a pen) were collected twice daily at 0700 and 1600 from d 73 to 78 from at least 2 steers within each pen. Only warm specimens were collected to guarantee the collection of fresh samples. At each collection time, samples were immediately frozen stored at -20 ˚C. At the end of the collection period (d 78), fecal samples were thawed overnight and a subsample (100 g, as-is basis) of homogenized feces from each collection was obtained and composited by pen. Steers within each pen were not individually identified for fecal samples, and pen served as the experimental unit. Before laboratory analyses, composited samples were dried at 55 ˚C for 96 h (forced-air oven). Diets, orts, and fecal samples were ground in a Wiley mill (Thomas Scientific, Swedesboro, NJ) to pass a 1 mm screen and stored until analysis.

Laboratory analyses

Diet, feed refusals (when representing more than 5% [DM basis] of the amount of feed offered the previous d), and fecal samples were analyzed for acid insoluble ash (AIA), DM, ash, NDF, ADF, ether extract, and starch. The AIA concentrations were determined using 2N HCl analysis [6], in triplicate. All other sample analyses were conducted in duplicate, and corrected for laboratory DM, determined by drying samples at 100 ˚C in dry oven for 12-24 h. Ash and OM were determined by ashing at 550 ˚C for 4 h [7]. The NDF and ADF were determined in sequence using a fiber analyzer (Ankom Technology, Macedon, NY), with the addition of sodium sulfite, α-amylase for the NDF procedure, and by subtracting ash from residues [8]. Hemicellulose was calculated as the difference between NDF and ADF. For N determination, ground feed, orts, and fecal samples were analyzed using the combustion method (Leco, Model TruMac N, St Joseph, MI; Method 4.2.10) [9]. Starch and ether extract were evaluated by a commercial laboratory (ServiTech Laboratories, Amarillo, TX). Apparent total tract digestibility of DM, OM, CP, NDF, ADF, hemicellulose, ether extract, CP, and starch was determined using the following equation: 100-100 × [(AIA concentration in feed/AIA concentration in feces) × (nutrient concentration in feces/nutrient concentration in feed)]. Nutrient intakes were corrected for orts (i.e. orts-corrected quantity of nutrient consumed divided by orts-corrected quantity of DM consumed). Dietary energy values (Mcal/kg) were calculated from the growth performance data [10].

Feeding behavior

On d 126, a 24 h feeding behavior evaluation was performed. Visual observations were taken every 5 minutes by trained personnel, for the following behaviors: eating, drinking, ruminating, resting, and active. Personnel (2 people for every 3 h shift) were available for the visual evaluation of the 32 pens. Notes of the number of animals performing each respective activity within pen were taken (on average, 2-3 min were necessary to access all pens). As pen was considered the experimental unit, no individual animal identification was recorded. Chewing activity was accounted for by adding time spent eating with total time spent ruminating. All animals were evaluated for all periods during 24 h. Time spent in each activity was expressed as percent per d. Eating, rumination and chewing times per kg of DM and NDF consumed were calculated as follows: minutes spent in each activity/DMI or NDF intake, in kg. Nutrient intakes were corrected for orts (i.e. orts-corrected quantity of nutrient consumed divided by orts-corrected quantity of DM consumed).

Statistical analyses

Only descriptive data were recorded during growing phase. Following a split plot design, data for the finishing phase (growth performance, carcass characteristics, and apparent digestibility) were analyzed using the GLIMMIX procedures of SAS (SAS Inst. Inc. Cary, NC). Pen served as the experimental unit; dietary treatment and growing system were fixed effects, with BW-block used as a random effect. Binomial proportions were used to analyze quality grade and liver scores with the GLIMMIX procedures of SAS with block included as a random effect, and using the inverse-link function of SAS for non-normal distribution. Bias of degrees of freedom was adjusted by the Kenward-Roger method. Least square means, generated for independent variables and their interaction (where appropriate), were separated using the PDIFF option, and differences were considered significant at $P < 0.05$.

Results and Discussion

Growing phase

No statistical analyses were performed for the growing phase, because animals were managed as a single group within each system. Initial BW of steers grazing forage-sorghum was 292 kg and steers placed on 65% concentrate diet averaged 236 kg. Final BW of steers grazing sorghum was 362 kg and steers placed on 65% concentrate diet averaged 387 kg. At the end of the growing phase (111 and 92 d), steers in the grazing and bunk-fed systems had 0.63 and 1.64 kg of ADG, respectively.

High prussic acid concentrations are commonly observed in the early vegetative stages of growth of forage-sorghum varieties, with concentrations that can reach 0.2 to 0.3% of the plant DM [11], while plants with 0.02% may be already considered dangerous. To avoid poisoning, it is recommended to graze forage-sorghum when the canopy height reaches at least 45 to 60 cm. Generally, sorghum will not be planted at the same time, and therefore, the canopy height at grazing may vary significantly, particularly for long grazing periods. The current study was managed to have animals in paddocks of recommended canopy height to avoid grazing of sorghum re-growth. The quality of the forage decreases with the maturity of the plant. In a study with BMR sorghums used for grazing animals, Hanna et al. observed that the *in vitro* digestibility of plant leaves harvested in earlier stages of growth (28 d after sowing) was 7.2% greater than those harvested in latter stages of maturity [12]. The improvements in digestibility associated with less mature plants could lead to greater animal growth performance. In addition to forage nutrient composition, the leaf to stem ratio and other plant characteristics that affect intake may also affect animal growth performance. Even in situations of high quality forage types, grazing of mature plants can result in decreased DMI and decreased animal growth performance. Fonseca et al. [13], studied grazing management targets for forage sorghum. A canopy height of 50 cm was discussed as the management goal, because the forage was this height, the DMI by the animals was maximized. In addition, at a canopy height of 50 cm, the leaf to stem ratio (60:40) might be maximized. In addition to the quality and quantity of forage consumed, as animals grow, maintenance energy requirements increase, decreasing the energy available for gain if the DMI does not change. For the sorghum material used in the current study, animals were placed on the forage-sorghum pastures when the forage height was optimal (approximately 60 to 70 cm), but over time, the plants grew to canopy heights of up to 2 m by the end the grazing period, mainly due to favorable rainfall events after animals entered the area. A large amount of forage was available for animal consumption, however, under these conditions, forage quality and DMI may have been decreased compared with early grazing period. Such anecdotal observations might explain the current BW gains observed in this system.

To our knowledge, no grazing literature data for sorghum bmr-6 AF7401 has been reported to current date. However, the ADG (0.63 kg per d) observed for steers grazing current hybrid (growing phase) is within gain range observed by studies using similar summer annual grasses. McCartor and Rouquette evaluated the growth performance of weanling calves grazing pearl millet [*Pennisetum* sp.] at three grazing pressures and observed ADG from 0.27 to 1.01 kg [14], depending on the year of study and grazing pressure, averaging on gains similar to the ones observed in the current research. On the other hand, early grazing of high quality pastures yielded growing steers ADG of 0.95 kg per d, without any protein or energy supplementation [15]. McCuistion et al. studied the growth performance of stocker cattle grazing sorghum-sudangrass hybrids under various stocking rates. For the brown mid-rib hybrid, ADG averaged in 0.96 kg in a 56-d period [16].

Based on the NE values calculated from animal performance, the 65% concentrate diet fed in the bunk-fed system seemed to have greater energy density than the *Sorghum forage* consumed by steers in the forage-sorghum grazing system. The calculated NEm and NEg for the 65% concentrate diet were 1.87 and 1.22 Mcal/kg DM, respectively, whereas, according to NRC, the NEm and NEg values for sorghum-sudangrass pasture (which is similar to our grazed forage) are 1.47 and 0.88 Mcal/kg, respectively [17]. Although greater intake of energy during the growing phase may produce great animal growth performance during the growing phase, it can potentially decrease growth performance during the finishing phase [18,19]. Thus, by analyzing the growing and finishing phases together it is possible to measure overall feed use and efficiency.

Another aspect in the current evaluation to be considered is the initial BW of the steers. The initial BW for the two growing systems was determined immediately after cattle were unloaded. In addition, previous nutrition as well as the time animals were in the marketing system and on the transport vehicle could also affect shrink and significantly change the initial BW of the growing phase. Finally, another crucial item that deserves comment is the origin of the steers, because they were purchased from multiple sources (commercial setting). Genetics and nutritional management of the steers in the two growing systems may affect animal growth performance during the growing period. However, regardless of the potential sources of variation in the research steers, the finishing phase dietary treatments were randomly assigned within each growing group, in order to minimize any source of potential bias due to cattle origin.

Growth performance during the finishing phase

Dry matter intake, ADG, and G:F during the finishing phases are presented in Table 2. Grazing system × finishing forage interaction was not significant (P = 0.30) for initial BW. Steers fed each silage type started the finishing study with similar BW (P = 0.45). Steers grown on sorghum pasture started the finishing phase 5 kg lighter (P < 0.01) than bunk-fed steers (391 *vs.* 396 kg). Although the difference in initial BW between the systems is small, it is possible that steers started the finishing period with different body compositions. In a study comparing plane of nutrition during the growing phase, Sainz et al. observed that at the end of the growing phase animals fed low-concentrate diets had 80% more gastrointestinal tract fill, 67% less back-fat, 59% less KPH%, 40% less abdominal fat, 50% less marbling score, and 42% less empty body fat, than the cattle fed high-concentrate diets ad libtum [18]. Therefore, it is possible that steers bunk-fed the 65% concentrate diet during the growing phase had a greater body fat content than steers that grazed the sorghum forage.

No growing system × finishing forage interaction was observed (P ≥ 0.44) for final BW or for adjusted final BW. Steers originating from the grazing system had 55 kg greater (P < 0.01) final BW than bunk-fed steers (661 *vs.* 606 kg). The differences in final BW of cattle originating

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from different growing systems are a result of the greater ADG in the grazing growing system than the bunk-fed growing system. No growing system × finishing forage interactions were observed for the DMI variables ($P \geq 0.16$), except for a tendency for interactions for DMI from d 0 to end ($P = 0.06$), and from d 0 to d 56 ($P = 0.07$), in which bunk-fed backgrounded steers that received corn silage during the finishing phase had the lowest DMI compared with steers that grazed sorghum during the growing system that received corn-or sorghum-silages during the finishing phase; whereas, the steers that were bunk-fed during the growing phase and that received sorghum-silage during the finishing phase had intermediate DMI. Steers that grazed forage sorghum during the growing phase had grater DMI ($P < 0.01$), than steers bunk-fed during the growing phase. From d 0 to the end of finishing, steers that grazed sorghum during the growing phase had 23% greater ($P < 0.01$) DMI than steers bunk-fed during the growing phase, with the greatest difference occurring during the d 56 to 112 period, in which steers that grazed sorghum during the growing phase had 28% greater ($P < 0.01$) DMI than steers bunk-fed during the growing phase. According to the NRC, the percentage of body fat may affect DMI [20]. As animals mature, adipose tissue may exert a feedback role in controlling DMI, with a decrease in DMI of 2.7 percent for each 1 percent increase in body fat, over the range of 21.3 to 31.5 [21]. If steers that grazed sorghum during the growing phase had less body fat percentage than steers that were bunk-fed during the growing phase, the body fat could have exerted less effect on DMI, resulting in the greater DMI observed for steers that grazed forage sorghum compared with steers bunk-fed during the growing phase.

For ADG, no growing system × finishing forage interaction was observed ($P \geq 0.19$), with exception in a tendency ($P = 0.06$) for an interaction of ADG between d 56 to 112, in which steers that were bunk-fed during the growing phase and fed sorghum-silage during the finishing phase tended to have greater ADG than the steers fed corn silage; whereas, steers that grazed sorghum during the growing phase had the opposite result. Generally, during all stages of the finishing phase, steers that grazed sorghum during the growing phase gained more weight than steers that were bunk-fed during the growing phase ($P < 0.01$), explained by a compensatory gain observed for these steers. Overall, regardless of silage type in the finishing diet, steers that grazed sorghum during the growing phase had 30% greater ADG than steers that were bunk-fed during the growing phase. During the ractopamine feeding period, no growing phase or finishing phase diet differences ($P = 0.16$) were observed in growth performance. Generally, finishing diet silage source did not ($P \geq 0.26$) influence ADG in any of the periods, although there was a tendency ($P = 0.06$) for greater (5%) carcass-adjusted overall ADG for steers fed corn silage compared to the steers fed sorghum silage. Such a tendency for greater ADG in steers fed corn silage than sorghum-silage might be explained by potential less NE of sorghum silage, which was not fully compensated by the greater DMI of steers consuming this forage during the finishing phase.

No ($P \geq 0.16$) growing system × finishing forage interactions were obtained for G:F. During the overall feeding period, steers that grazed sorghum during the growing phase were 5% more efficient ($P < 0.01$) than steers that were bunk-fed during the growing phase. This effect appeared to occur primarily during the first 56 d of the finishing study, in which the steers that grazed sorghum during the growing phase were 19% more efficient ($P < 0.01$) during the finishing phase than steers that were bunk-fed during the growing phase. Both growing systems had similar G:F from d 56 to 112 ($P = 0.88$). These results contrast to the study completed by McCurdy et al. [19], where calf-fed steers had greater G:F during the finishing period than steers that grazed wheat pasture during the growing phase. The G:F in the finishing phase of Sainz et al. agree with the results of the present study as steers consuming a low concentrate diet in the backgrounding phase had greater G:F in the finishing period than those consuming a high concentrate diet during the growing phase [18].

Steers fed 20% corn silage in the steam-flaked corn-based finishing diets had greater ($P < 0.01$) G:F than steers fed 20% sorghum silage diet during all the evaluated periods. Overall, steers fed corn silage had 10% greater G:F than steers fed sorghum silage during the finishing phase. No significant differences ($P \geq 0.15$) for ADG and G:F (including no growing system × finishing forage interaction, or main effects of growing system and finishing forage) during the period that ractopamine was fed was observed, although no interaction between silage type and ractopamine hydrochloride was expected for those final 28 d of the finishing phase. Corn and sorghum silages are reported by the NRC as 100% forage. However, it is known that large proportions of grain can be observed in silage, and these proportions can be highly variable [17]. In the current study, the ensiled forages contained 36.1 and 27.4% starch; and 32.5 and 37.8 % NDF (DM basis), for corn and sorghum silages, respectively. Moreover, these nutrients have different physical and chemical characteristics (i.e. starch availability and lignification), potentially resulting in considerably distinct sources of forage. As a result, perhaps cereal crop silages should be treated as a combination of a source of roughage (generally high-quality forage) and grain (with a range of starch availability). Therefore, the lesser starch and greater NDF contents observed for sorghum silage material could negatively affect the energy content of the diet, which ratifies a reduced G:F observed for steers fed sorghum silage compared to those steers fed corn silage in current finishing diets.

Carcass characteristics

Effects of the growing system and the finishing diet silage type on carcass characteristics are presented in Table 4. No ($P \geq 0.21$) growing system × finishing forage interactions were obtained for any of the carcass parameters measured. Carcasses from steers that grazed sorghum during the growing phase were 8% heavier ($P < 0.01$) than carcasses from steers bunk-fed during the growing phase which is indicative of the greater final BW observed in grazing backgrounded steers. The dressing percent was influenced by the growing system ($P < 0.01$) and by the finishing forage source ($P = 0.03$), with steers that grazed sorghum during growing phase dressing less than steers bunk-fed during the growing phase. Regardless of growing system, steers fed corn silage during finishing had greater dressing percent than steers fed *Sorghum silage* during the finishing phase. Carcasses from steers that were bunk-fed during the growing phase had 23% greater 12^{th} rib fat depth ($P < 0.01$) than carcasses of steers that grazed sorghum during the growing phase; whereas, fat thickness was not affected ($P = 0.14$) by silage type fed during the finishing phase. The greater dressing percent and fat thickness of carcasses originating

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from steers bunk fed the 65% concentrate diet may be related to the initial body composition, although not measured in current study. These results agree with those of Sainz et al. who reported thicker back fat in carcasses of steers that were backgrounded on high-concentrate diets than low-concentrate diets [18]. Due to the greater DMI of steers fed sorghum silage than corn-silage during the finishing period, and the potential greater bulk of the sorghum silage based diet (i.e. less grain content and greater forage compared with corn silage), steers fed sorghum silage were likely to have greater gut fill than steers fed corn silage, potentially causing the reduced dressing percent.

No effects ($P \geq 0.57$) of growing system × finishing diet silage type were observed for quality grade, which agrees with Sainz et al. [18]. Only seven steers in the current study had liver abscesses that scored as A: 4 were from livers of steers that grazed sorghum and were fed *Sorghum silage* during finishing, 2 were from steers fed corn silage that were bunk fed during the growing phase, and 1 was from a steer fed sorghum silage than was bunk fed during the growing phase.

Total tract apparent nutrient digestibility

Effects of the growing system and silage type during the finishing phase on apparent total tract digestibility are presented in Table 5. The DMI during the period of the digestion study followed the same pattern as during the overall finishing period. No interaction ($P \geq 0.16$) between growing system × finishing diet forage interaction was observed for any of the digestion variables. The DMI was 33% greater ($P < 0.01$) for steers that grazed sorghum during the growing phase than steers that were bunk-fed during the growing phase. The growing system did not ($P \geq 0.22$) affect digestibility of any of the nutrients assessed. It is not clear if feeding of high cellulose diets can have long term effects on later fiber degradation in ruminants subjected to abrupt change in diets (eg: grazing to high-starch finishing diet), but no clear effect was observed in the current study. In addition, fiber requires more time for degradation in the rumen compared with other nutrients, and thus it is one component of the diet most likely to be affected by the particle rate of passage. High-concentrate finisher diets, may not offer ruminal fermentation favorable conditions to expose dramatic differences in fiber degradation. Moreover, as the steers that originated from the sorghum grazing system had greater DMI during the finishing phase than steers that were bunk-fed during the growing phase, it might be expected that more VFA would be produced from ruminal fermentation, compared with the steers from the bunk-fed system. As a result, decreased ruminal pH might occur in the steers with greater DMI. According to Casamiglia et al. the factor with the greatest impact on ruminal fiber degradation is the environmental pH [22]. However, we need to also consider other characteristics of the diet, such as physical effectiveness of the fiber and forage particle size [23].

Forage source in the finishing diet affected the digestibility of most nutrients. Steers consuming diets containing corn silage had 11% greater ($P < 0.01$) DM digestibility that steers consuming sorghum silage as the forage source. The same pattern was observed for OM digestibility, with the OM digestibility of the diet containing corn silage being 10% greater ($P < 0.01$) than the sorghum-silage-based diet. This greater DM and OM digestibility of the corn silage-based diet is reinforced by the greater digestibility of the main nutrients in the diets. Replacing sorghum-silage with corn silage on a 1:1 basis increased ($P < 0.01$) the digestibility of starch, CP, and ether extract by approximately 8, 9, and 2% units, respectively.

There were no effects ($P \geq 0.11$) of finishing diet on fiber digestibility in the current study. As mentioned previously, the low silage inclusion rate (20%, DM basis), may not provide potential to affect overall dietary fiber digestibility between diets. Additionally, high-concentrate diets may not offer ideal conditions for fiber fermentation in the rumen, which may minimize the ability to detect differences in fiber digestibility.

Calculated dietary energy density

Effects of growing system and the silage type on finishing diet energy density are presented in Table 5. A growing system × finishing forage interaction ($P \leq 0.02$) was obtained for the calculated energy values. Regardless the variable (NEm, NEg, or ME), cattle fed the corn silage finishing diet and bunk-fed during the growing phase had the greatest dietary energy density, followed by the corn silage diet fed to steers that grazed the sorghum during the growing phase. Both sorghum-silage finishing treatments had similar dietary energies, although they were lesser than the corn silage-based finishing diet. The equations Vasconcelos and Galyean used to calculate dietary energy from growth performance account for composition of gain at different weights [10]. According to percentage of mature weight, proportions of gain allocated to protein and fat define how the energy of the diet was used. Average BW during the finishing period for steers that were bunk-fed and steers that grazed sorghum during the growing phase were 500 and 526 kg, respectively. In the calculations, it was assumed that the mature weight is equal to the final BW observed in the current study. Thus, these average BW are 83 and 80% of the mature weight, for steers that were bunk-fed and steers that grazed sorghum during the growing phase, respectively. As a result, the steers that were bunk-fed during the growing phase may have deposited more body fat during the finishing phase than steers that grazed sorghum during the growing phase. As fat contains more energy than protein, steers that were bunk-fed during the growing phase had greater values for dietary energy than steers that grazed sorghum during the growing phase. According to the NRC, ME is approximately 82% of the value of DE [17]. Because the corn silage-based diet had 10% greater OM digestibility than the *Sorghum silage* diet, it would be expected to have greater ME and consequently, greater NEm and NEg. The magnitude of change in the ME may not follow exactly the magnitude in the OM digestibility, because the proportions of each nutrient's change (fat *vs.* CP, *vs.* carbohydrate) will define the final energy value. Also, different nutrients are metabolized by the animals in different pathways.

Feeding behavior

Effects of growing system and finishing diet silage type on feeding behavior of finishing steers is presented in Table 7. No growing system × finishing forage interaction were obtained ($P \geq 0.13$) for any of the behavioral measurements. Steers coming from the grazing growing system tended ($P = 0.07$) to spend more time (5%) chewing than steers bunk-fed during the growing phases. Although these findings follow the same pattern as the differences in finishing diet DMI of steers coming from the different growing systems, the magnitude of the increase does not agree with the increase in DMI (23% greater DMI for grazing over bunk-fed steers). Accounting for the intake of

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DM and NDF, steers that were bunk-fed during the growing phase spent, on average, 18% more time ($P < 0.01$) ruminating, eating, and chewing per unit of DMI or NDF intake than steers that grazed sorghum during the growing phase. Assuming that steers from different systems ruminate a feed boli at similar rates (quantity of feed per time of rumination), digesta from steers that grazed sorghum during the growing phase may have been less chewed than feed boli from steers that were bunk-fed during the growing phase. These observations, and the numerically less total tract apparent digestibility observed for steers from the sorghum grazing growing system, is possibly due a greater ruminal rate of passage in this group. Steers coming from the sorghum grazing growing system spent 47% more time drinking water ($P = 0.04$) than steers from the bunk-fed system. Time spent drinking is possibly related to the greater DMI and ADG during the overall feeding period in the current study observed for steers from the sorghum grazing system. Additionally, at the time steers were subjected to the behavioral observation, steers from the sorghum grazing system were heavier than steers from the bunk-fed system.

Forage source influenced the quantity of time steers spent ruminating ($P = 0.02$), eating ($P = 0.01$), and chewing ($P < 0.01$) each day, with steers fed sorghum silage spending more time with these activities, than steers fed corn silage in the finishing phase. Time active (activity other than rumination, eating, and drinking) or drinking water was not affected by the finishing diet forage source ($P \geq 0.70$). Finishing diet forage source did not influence the time steers spent with the various activities (rumination, eating and chewing) per kg of DMI ($P \geq 0.14$); however, steers fed corn silage spent more time ($P < 0.01$) ruminating (15%) and chewing (12%) per kg NDF intake compared with steers fed sorghum silage.

Conclusions

Grazing small grains crop (sorghum) or bunk-feeding a 65% concentrate diet during growing phase did not induce a forage (corn or sorghum silages) of preference during the finishing phase of beef steers. Compensatory growth of animals that grazed during growing phase induced better finishing phase growth performance than those bunk-fed a more energy dense diet during growing period. Replacing corn silage with sorghum silage in beef cattle finishing diets at a relatively high inclusion rate (20% DM basis) provided less dietary energy and decreased animal growth performance. Further evaluation of these growing and finishing systems must consider economics and water use.

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