BioOne COMPLETE

Use of barley silage or corn silage with dry-rolled barley, corn, or a blend of barley and corn on predicted nutrient total tract digestibility and growth performance of backgrounding steers

Authors: Sutherland, B.D., Johnson, J.A., McKinnon, J.J., McAllister, T.A., and Penner, G.B.

ARTICLE

Use of barley silage or corn silage with dry-rolled barley, corn, or a blend of barley and corn on predicted nutrient total tract digestibility and growth performance of backgrounding steers

B.D. Sutherland, J.A. Johnson, J.J. McKinnon, T.A. McAllister, and G.B. Penner

Abstract: The objective of this study was to determine the effects of feeding barley silage (BS) or corn silage (CS) with dry-rolled barley (BG), dry-rolled corn (CG), or a blend of barley and corn grain (BCG), on growth performance and nutrient digestibility, the latter predicted using near-infrared spectroscopy for backgrounding cattle. Steers ($n = 288$) were stratified by body weight (BW) into 24 pens and pens were randomly assigned to one of six treatments ($n = 4$) in a 2×3 factorial design. Main factors included BS or CS in combination with BG, CG, or BCG. There were no silage × grain interactions. Dry matter intake (DMI; $P = 0.018$) and final BW ($P = 0.004$) were greater for steers fed CS than BS, but average daily gain (1.01 kg d^{-1}) and gain-to-feed ratio (0.10 kg kg^{-1}) were not affected by silage or grain source. Steers fed CS also had greater dry matter, organic matter, crude protein (CP), acid detergent fiber (ADF), starch, and gross energy digestibility values ($P < 0.01$) than BS. Feeding BG increased starch, neutral detergent fiber, ADF, and CP digestibility values ($P \leq 0.01$) over CG and BCG. Relative to BS, feeding CS increased DMI, final BW, and nutrient digestibility, whereas dry-rolled BG improved nutrient digestibility when compared with CG and BCG in backgrounding diets.

Key words: barley grain, barley silage, short-season corn, corn grain.

Résumé : L'objectif était de déterminer les effets de donner comme aliment l'ensilage d'orge (BS — « barley silage ») ou de maïs (CS — « corn silage ») avec de l'orge floconné à sec (BG — « dry-rolled barley grain »), le maïs floconné à sec (CG — « dry-rolled corn grain »), ou un mélange de grains d'orge et de maïs (BCG — « barley and corn grains »), sur la performance de croissance et la digestibilité des éléments nutritifs prévues en utilisant la spectroscopie du proche infrarouge chez les bovins en semi-finition. Les bovins ($n = 288$) ont été stratifiés selon leur poids corporel (BW — « body weight ») en 24 enclos, puis les enclos ont été assignés aléatoirement à l'un de 6 traitements ($n = 4$) dans un design expérimental factoriel 2×3. Les facteurs principaux incluaient le BS ou le CS en combinaison avec BG, CG, ou BCG. Il n'y a pas eu d'interactions ensilage × grains. La consommation des matières sèches (DMI — « dry matter intake »; $P = 0,018$) et les BW finaux ($P = 0,004$) étaient plus élevés pour les bovins ayant reçu le CS que le BS, mais il n'y a pas eu d'effet de la source d'ensilage ou de grains sur le gain moyen quotidien (1,01 kg d^{-1}) ni l'indice de consommation (0,10 kg kg^{-1}). Les bovins ayant reçu le CS avaient aussi de plus grandes valeurs de digestibilité des matières sèches, matières organiques, protéines brutes (CP — « crude protein »), fibres au détergent acide (ADF — « acid detergent fibre »), amidon, et énergie brute ($P < 0,01$) que ceux ayant reçu le BS. Nourrir les bovins de BG a augmenté les valeurs de digestibilité de l'amidon, des fibres au détergent neutre, d'ADF, et de CP ($P \leq 0,01$) par rapport aux CG et BCG. Par rapport au BS, nourrir les bovins aux CS a augmenté le DMI, le BW final, et la digestibilité des éléments nutritifs; tandis que les BG floconnés à sec ont amélioré la digestibilité des éléments nutritifs lorsque comparé aux CG et BCG dans les diètes de semi-finition. [Traduit par la Rédaction]

B.D. Sutherland, J.A. Johnson, J.J. McKinnon, and G.B. Penner.* Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, SK S7N 5A8, Canada.

T.A. McAllister. Agriculture Canada Research Centre, Lethbridge, AB T1J 4B1, Canada.

Corresponding author: G.B. Penner (email: greg.penner@usask.ca).

*G.B. Penner currently serves as an Editor-in-Chief; peer review and editorial decisions regarding this manuscript were handled by Dengpan Bu.

Introduction

In Western Canada, barley silage (BS) and barley grain (BG) are commonly used in diets for backgrounding and finishing cattle. However, development of short-season corn varieties has increased the potential for corn production in Western Canada, particularly for silage, due to greater yields than barley (Lardner et al. 2017). In addition to greater yields, corn grain (CG) and corn silage (CS) have greater starch but lower protein concentrations, and reduced rates and extents of starch and protein degradation in the rumen relative to BG and BS (Tothi et al. 2003). Given the marked differences in the concentrations of starch and crude protein (CP) as well as rates of fermentation, it may be possible to combine BS and CS and cereal grains as a strategy to balance ruminal fermentation and intestinal starch supply for efficient digestion.

Despite well-documented effects of feeding CG and CS in backgrounding diets for beef cattle in the United States (Hedrick et al. 1983; Pelletier et al. 2010), it is important to recognize that short-season varieties of corn grown in Western Canada result in CS that has lower starch and higher protein concentrations than conventional cultivars (Chibisa and Beauchemin 2018). In addition, recent evidence suggests that there are marked differences in starch digestibility among short-season hybrids (Miorin et al. 2018). Thus, research is warranted to evaluate the effects of feeding CS from short-season corn varieties on growth performance of backgrounding cattle.

We hypothesized that cattle fed diets containing CS rather than BS would have greater dry matter intake (DMI) and average daily gain (ADG) when fed with a blend of barley and corn grain (BCG) than cattle fed BG or CG alone. The objective of this study was to determine the effects of BS or CS when fed with dry-rolled barley, dry-rolled corn, or a combination of BG and CG on DMI, ADG, and estimated total tract digestibility of backgrounding cattle.

Materials and Methods

The use of steers in this study was conducted in accordance with the Canadian Council on Animal Care (Ottawa, ON, Canada), and animal use was approved by the University of Saskatchewan Animal Research Ethics Board (protocol 20100021).

Silage production

Crop production for both barley and corn followed conventional practices used in Western Canada. Barley silage (CDC Copeland; SeCan, Kanata, ON, Canada) was planted on 19 May 2016 after being treated with a fungicide (Rancona Pinnacle at 0.3 L 100 kg^{-1} of seed; Arysta LifeScience Corporation, Cary, NC, USA). Anhydrous ammonia was applied at 64.6 kg ha^{-1} along with Mesz granular fertilizer (Mosaic Company, Plymouth, MN, USA) supplying 2.6 kg ha^{-1} N, 8.6 kg ha^{-1} P, 0.2 kg ha^{-1} Zn, and 2.2 kg ha^{-1} S at seeding. The crop was sprayed with Curtail M (0.3 L ha^{-1}; Corteva Agriscience, Indianapolis, IN, USA), Buctril M (0.2 L ha^{-1}; Bayer Crop Science, Thane, India), and Bison (0.2 L ha^{-1}; Adama Canada Ltd., Winnipeg, MB, Canada). The crop was swathed, chopped (theoretical chop length of 9.5 mm), and ensiled on 28 July 2016 (Table 1). Silage was inoculated with Biomax 5 (Chr. Hansen Inc., Milwaukee, WI, USA) at a rate of 1 g t^{-1}. There was a total of 855 growing degree days for the barley crop prior to swathing. Growing degree days were calculated on a daily basis by taking the average of the minimum and maximum temperatures and subtracting 5 °C (Rosser et al. 2013).

Corn (Pioneer 7213R; Dupont Pioneer, Mississauga, ON, Canada) was planted 27 May 2016 (12 950 plants ha^{-1}). Anhydrous ammonia was applied at 72.1 kg ha^{-1} along with a granular fertilizer supplying 82.1 kg ha^{-1} N and 27.4 kg ha^{-1} P at seeding. The crop was sprayed with R/T 540 twice (0.3 and 0.3 L ha^{-1}; Monsanto Canada Inc., Winnipeg, MB, Canada). Corn was chopped to a theoretical chop length of 9.5 mm on 31 Aug. 2016 using a kernel processer adjusted to have a 2 mm gap, and an inoculant was added (1 g t^{-1} of Biomax 5; Chr. Hansen Inc.; Table 1) at the time of ensiling. The corn received 1940 corn heat units from seeding to harvest which was slightly lower than the 25 yr normals for Saskatoon (SK, Canada) ranging from 2200 to 2299 corn heat units (Government of Saskatchewan 2016).

A total of 288 steers were sourced through a local auction market with mean body weight (BW) of 306 ± 17 kg. Upon arrival, steers were given a management tag, vaccinated with Bovashield Gold One Shot (Zoetis, Parsippany-Troy Hills, NJ, USA), Ultrabac 7/Somubac (Zoetis), and Bimectin (Bimeda Canada, Cambridge, ON, Canada) was topically applied. Steers were also implanted upon arrival with Ralgro (36 mg zeranol; Merck Animal Health, Madison, NJ, USA). Subsequently, steers were stratified by BW (341.1 ± 0.4 kg) into one of 24 pens with four pens per treatment and 12 steers per pen using a 2 × 3 factorial treatment arrangement. Pens were 12 m × 24 m and had a 3.3 m high windbreak fence at the back of the pen. Diets included (Table 2): BS with BG (BS–BG); BS with CG (BS–CG); BS with BCG (BS–BCG); CS with CG (CS–CG); CS with BG (CS–BG); and CS with BCG (CS–BCG). Corn silage and BS were included at 55% of the diet on a dry matter (DM) basis. Both corn and BG were dry rolled with corn ground to allow for 5% of the material to pass through a 1 mm sieve, and barley processed to a processing index of 65%. When calculated on the basis of a processing index, the CG had a processing index of 83%. Diets were formulated to

Table 1. Chemical composition of the cereal silage and cereal grain sources.

	Ingredient			
Variable	Barley silage	Corn silage	Corn grain[a]	Barley grain[a]
DM (%)	40.7 ± 2.05	36.2 ± 2.06	87.5 ± 1.51	87.6 ± 0.58
OM (% of DM)	94.3 ± 0.21	95.4 ± 0.06	98.9 ± 0.72	97.8 ± 0.03
CP (% of DM)	10.2 ± 0.17	9.3 ± 0.12	8.8 ± 0.17	11.8 ± 0.46
NDF (% of DM)	48.4 ± 0.67	43.5 ± 0.17	9.9 ± 0.56	18.0 ± 0.84
ADF (% of DM)	30.1 ± 0.42	26.5 ± 0.46	3.7 ± 0.25	7.2 ± 0.32
Starch (% of DM)	21.4 ± 0.60	29.2 ± 0.59	72.9 ± 1.70	59.4 ± 0.97
Ether extract (% of DM)	2.74 ± 0.20	2.81 ± 0.09	4.00 ± 0.31	2.27 ± 0.10
Ca (% of DM)	0.30 ± 0.01	0.23 ± 0.01	0.02 ± 0.01	0.06 ± 0.00
P (% of DM)	0.25 ± 0.01	0.25 ± 0.01	0.30 ± 0.02	0.38 ± 0.01

Note: DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; Ca, calcium; P, phosphorus. For all ingredients, $n = 3$ and data are presented as the mean ± standard deviation.

[a]Both corn and barley grain were dry rolled with corn ground to allow for 5% of the material to pass through a 1 mm sieve resulting in processing indexes of 65% and 83%, respectively.

Table 2. Ingredient inclusion rate and chemical composition of diets composed of barley silage (BS) or corn silage (CS) with dry-rolled barley (BG), corn (CG), or an equal blend of barley and corn grain (BCG) fed to beef steers.

	BS			CS		
Item (% of DM)	BG	CG	BCG	BG	CG	BCG
BS	55.00	55.00	55.00	—	—	—
CS	—	—	—	55.00	55.00	55.00
BG	31.44	—	15.61	31.18	—	15.48
CG	—	30.89	15.61	—	30.72	15.48
Canola meal	8.00	8.00	8.00	8.00	8.00	8.00
Urea	—	0.47	0.23	0.27	0.72	0.50
Premix pellet[a]	5.56	5.56	5.56	5.56	5.56	5.56
DM	53.66 ± 1.94	53.68 ± 1.88	53.66 ± 1.89	49.26 ± 2.21	49.28 ± 2.17	49.26 ± 2.18
OM	93.88 ± 0.09	93.71 ± 0.22	93.87 ± 0.13	94.28 ± 0.07	94.16 ± 0.28	94.23 ± 0.18
CP	13.22 ± 0.23	13.56 ± 0.12	13.38 ± 0.16	13.44 ± 0.12	13.74 ± 0.06	13.6 ± 0.03
NDF	35.60 ± 0.32	33.00 ± 0.37	34.3 ± 0.34	32.85 ± 0.19	30.27 ± 0.14	31.55 ± 0.15
ADF	20.89 ± 0.33	19.77 ± 0.24	20.33 ± 0.28	18.87 ± 0.35	17.76 ± 0.2	18.31 ± 0.27
Starch	32.3 ± 0.53	36.17 ± 0.84	34.3 ± 0.66	36.5 ± 0.03	40.37 ± 0.53	38.46 ± 0.28
Ether extract	2.67 ± 0.11	3.19 ± 0.04	2.93 ± 0.07	2.7 ± 0.05	3.22 ± 0.04	2.96 ± 0.02
Ca	0.80 ± 0.03	0.79 ± 0.04	0.79 ± 0.03	0.76 ± 0.03	0.75 ± 0.03	0.75 ± 0.03
P	0.38 ± 0.01	0.35 ± 0.01	0.36 ± 0.01	0.38 ± 0.01	0.35 ± 0.01	0.36 ± 0.01

Note: DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; Ca, calcium; P, phosphorus. For all diets, $n = 3$ and data are presented as the mean ± standard deviation.

[a]Premix pellet contains: Ca, 9.20%; P, 0.32%; sodium, 1.64%; magnesium, 0.28%; potassium, 0.60%; sulfur, 0.12%; cobalt, 4.9 mg kg^{-1}; copper, 185 mg kg^{-1}; iodine, 16.6 mg kg^{-1}; iron, 84 mg kg^{-1}; manganese, 500 mg kg^{-1}; zinc, 558 mg kg^{-1}; fluorine, 100 mg kg^{-1}; vitamin A, 40 000 IU kg^{-1}; vitamin D3, 5000 IU kg^{-1}; vitamin E, 600 IU kg^{-1}; selenium, 2.00 mg kg^{-1}; monensin, 550 mg kg^{-1}.

meet or exceed nutrient requirements according to NASEM (2016) using samples of the feed ingredients collected prior to the start of the study. Diets were formulated to contain 13.5% CP with the inclusion of cereal silage being held consistent among treatments. Cereal grain inclusion rates were also similar for all diets allowing starch concentration to vary with treatment. Canola meal was included to increase the protein concentration of the diets, and urea was used to achieve isonitrogenous diets. Although this may alter the rumen degradable protein:rumen undegradable protein ratio of the diets, only CP was considered in dietary formulation. All diets included monensin (Elanco, Greenfield, IN, USA) to target 33 mg kg^{-1} DM. Steers were fed once daily between 0830 and 1100 to achieve voluntary intake. The amount of feed delivered was recorded daily.

Steers were weighed on two consecutive days at the beginning and end of the study to determine initial and final BW. During the study, steers were weighed every 2 wk on a single day. The ADG was determined by regressing unshrunk BW with days on feed. Net energy of maintenance (NE_m) and net energy of gain (NE_g) were calculated based on Zinn et al. (2002) and Zinn and Shen (1998). Feed bunks were cleaned on the same day as BW measurement and residual feed was weighed and removed. A sample of the refused feed was collected to determine DM and used to calculate DMI. At the time of refusal collection, a sample of all feed ingredients was collected, and all samples were dried in a forced-air oven at 55 °C for 72 h to determine DM. Dry samples were ground using a Retsch ZM 200 grinder (Haan, Germany) to pass through a 1 mm screen and sent to Cumberland Valley Analytical Services (Waynesboro, PA, USA) for analysis of organic matter (OM), CP, NDF, ADF, starch, ether extract, calcium, and phosphorus using wet chemistry as described by Johnson et al. (2020).

Fecal grain kernel assessment and predicted apparent total tract digestibility

On day 55, fresh fecal samples (maximum of 250 mL steer^{-1}) from at least four different steers (confirmed by visual observation of defecation) in each pen were collected from the pen floor and placed in a pail to achieve a final volume of 1 L. To avoid contamination from the pen floor, only fresh fecal pats were used and the top layer was scraped off. Fecal samples were then frozen and stored at −20 °C to later determine fecal nutrient composition using near-infrared (NIR) spectroscopy as well as DM determination. For analysis, samples were thawed and a 250 mL sample was weighed, placed in a 1.18 mm sieve, and washed with tap water until the water ran clear. The particles and fiber were weighed and dried for 48 h in a forced-air oven at 55 °C. Once dry, whole grain particles, partial grain particles, and fines were separated by cereal grain type and weighed. These fractions were expressed as a percent of fecal DM.

The remaining fecal material was weighed and dried in a forced-air oven at 55 °C for 72 h. Once dry, fecal material was weighed again and ground with a Retsch ZM 200 grinder (Haan, Germany) to pass through a 1 mm screen. The ground fecal material was used to predict fecal starch, digestible energy, and the digestibility of DM, OM, NDF, ADF, starch, CP, fecal starch, and gross energy using NIR spectroscopy (2400 RTW; Unity Scientific, Brookfield, CT, USA) with wavelengths between 1200 and 2400 nm using equations previously developed and validated for both backgrounding and finishing beef cattle by Jancewicz et al. (2016, 2017b). The original calibrations of Jancewicz et al. (2016) were developed using diets containing BS and a variety of cereal grains including barley, corn, and wheat, and these calibrations have been used to predict digestibility of diets containing short-season corn previously described by Johnson et al. (2020).

Statistical analysis

All data were analyzed using the mixed model of SAS version 9.4 (Cary, NC, USA) as a completely randomized design with a 2 × 3 factorial arrangement. The model included the fixed effects of silage type, cereal grain type, and their interaction. Pen was included as a random effect. Evaluation of grain kernels in feces was conducted using the mixed model of SAS version 9.4. However, data from treatments where it was impossible to have a specific kernel type in the feces (i.e., BS–BG diets could not have CG in the feces and CS–CG diets could not have BG in the feces) were removed from the analysis and denoted as not present in the results, indicating the outcome was not possible. All data were tested for normality and if data and the residuals were normally and independently distributed, data were analysed using the mixed model of SAS version 9.4. If assumptions for normality were not met, the data were analysed using the GlimMix procedure of SAS with binomial error structure and logit transformation. Presented means and standard error of mean were reverse transformed for data presentation. Differences were declared significant when $P < 0.05$, and means were separated using the Tukey's mean separation test.

Results

Although statistical analysis could not be conducted, the CS in this study was numerically greater in starch (29.2% vs. 21.4%) and numerically lower in CP (9.3% vs. 10.2%), NDF (43.5% vs. 48.4%), and ADF (26.5 vs. 30.1%) when compared with BS (Table 1). Likewise, CG had numerically greater starch (72.9% vs. 59.4%) and lower CP (8.8% vs. 11.8%), NDF (9.9% vs. 18.0%), and ADF (3.7% vs. 7.2%) than BG. The diets in the present study were balanced for CP through the use of canola meal and urea but allowed to vary in starch, NDF, and ADF concentrations based on the cereal silage and cereal grain sources used. As a result, diets for cattle fed CS had numerically greater starch and numerically lower NDF and ADF concentrations (Table 2).

There were no interactions between cereal silage source and cereal grain source for any of the variables evaluated ($P \geq 0.17$; Tables 3, 4, and 5) except the weight of the particles in feces that were retained on a 1.18 mm screen. As such, the main effects of cereal silage source and cereal grain source will be presented independently.

Although cattle were stratified by BW into pens and pens were randomly assigned to treatments, steers fed CS had a 1 kg greater starting BW than those fed BS ($P = 0.032$; Table 3). Likewise, steers fed CG tended ($P = 0.062$) to be lighter at the start of the study than those fed BG or BCG. Body weight at the end of the study was 8.3 kg greater ($P = 0.004$) for steers fed CS than for those fed BS, whereas final BW was not affected by cereal

↰ Published by NRC Research Press

Table 3. Growth, dry matter intake (DMI), and predicted energy density of diets composed of barley silage (BS) or corn silage (CS) with dry-rolled barley (BG), corn (CG), or an equal blend of barley and corn grain (BCG) fed to beef steers.

	BS			CS			P			
Variable	BG	CG	BCG	BG	CG	BCG	SEM	Silage	Grain	$S \times G$
Starting BW (kg)	341.0	340.3	340.8	342.0	340.8	341.5	0.40	0.032	0.06	0.82
Ending BW (kg)	457.8	461.3	459.5	468.3	468.5	466.8	3.03	0.004	0.70	0.83
ADG (kg d^{-1})	1.0	1.0	1.0	1.0	1.1	1.0	0.04	0.42	0.31	0.43
DMI (kg d^{-1})	10.0	9.6	9.7	10.2	10.9	10.6	0.45	0.018	0.86	0.39
G:F (kg kg^{-1})	0.11	0.11	0.10	0.10	0.10	0.10	0.01	0.14	0.65	0.86
NE$_m$ (Mcal kg^{-1})	1.04	1.04	1.09	1.06	1.06	1.08	0.08	0.93	0.90	0.99
NE$_g$ (Mcal kg^{-1})	0.51	0.51	0.55	0.52	0.52	0.54	0.07	0.93	0.91	0.98

Note: SEM, standard error of mean; $S \times G$, silage $\times$ grain interaction; BW, body weight; ADG, average daily gain; G:F, gain-to-feed ratio; NE$_m$, net energy of maintenance; NE$_g$, net energy of gain. The standard error for the interaction are reported. Net energy values calculated based on Zinn et al. (2002) and Zinn and Shen (1998).

Table 4. Apparent nutrient digestibility and fecal starch content predicted using near-infrared spectroscopy with dried feces collected from steers fed diets composed of barley silage (BS) or corn silage (CS) with dry-rolled barley (BG), corn (CG), or an equal blend of barley and corn grain (BCG).

	BS			CS			P			
	BG	CG	BCG	BG	CG	BCG	SEM	Silage	Grain	$S \times G$
Apparent nutrient digestibility (% of DM)										
DM	72.9	72.2	71.7	77.6	75.9	75.7	0.64	<0.001	0.070	0.60
OM	74.3a	73.0b	72.4b	78.9a	76.4b	76.2b	1.38	<0.001	<0.001	0.67
CP	64.9a	61.2b	62.5b	68.2a	62.6b	63.7b	0.58	0.001	<0.001	0.17
NDF	51.4a	50.1b	49.3b	54.0a	51.0b	52.1b	0.69	0.002	0.012	0.33
ADF	22.7a	18.1b	18.8b	29.2a	26.0b	26.6b	1.17	<0.001	0.008	0.79
Starch	93.6a	90.4c	91.9b	95.8a	91.3c	92.9b	0.42	0.001	<0.001	0.25
Gross energy	75.7a	74.9ab	73.2b	80.1a	77.8ab	78.6b	0.77	<0.001	0.039	0.27
Fecal starch (% DM)	9.7c	16.8a	14.9b	7.5c	17.0a	13.1b	0.90	0.11	<0.001	0.38

Note: SEM, standard error of mean; S $\times$ G, silage $\times$ grain interaction; DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber. Means within a column not sharing a common lowercase letter differ significantly at the $P < 0.05$ level for the cereal grain effect. The standard error for the interaction are reported.

grain type. Despite the greater final BW of CS versus BS fed cattle, ADG was not affected by cereal silage type or the cereal grain treatments averaging 1.1 kg d^{-1}. Dry matter intake was 0.8 kg d^{-1} greater ($P = 0.018$) for steers fed CS compared with those fed BS, but no differences were observed for the main effect of grain source. The gain-to-feed ratio (G:F) was not different among grain and silage sources. The calculated NE$_m$ and NE$_g$ based on BW, DMI, and ADG were not different among silage or grain sources.

Steers fed CS had greater predicted total tract DM, OM, CP, NDF, ADF, and starch digestibility values as well as a greater gross energy digestibility values ($P < 0.01$; Table 4) than steers fed BS. Fecal starch concentration was not affected by silage source. When evaluating grain source effects, steers fed BG had greater OM, CP, NDF, ADF, and starch digestibility values compared with CG or BCG, with steers fed BCG having greater starch digestibility than those fed CG. Fecal starch content was greatest for steers fed CG diets, intermediate for BCG diets, and least for BG.

The weight of the feces within a 250 mL subsample did not differ among silage source or grain source (Table 5). However, when fed BS with BG, weight of particles retained on a 1.18 mm sieve were greater than when fed CS with BG, with no differences among the other treatments (silage $\times$ grain interaction, $P = 0.036$). When reported as a proportion of the retained material, feeding BS increased the proportion of whole barley in feces relative to steers fed CS, and feeding CS increased the proportion of partial corn kernels in feces when compared with steers fed BS. There was very little to no whole corn present in the feces reflecting that both the CG and CS were processed. Barley grain diets had greater amounts of whole barley kernels compared with BCG diets ($P < 0.01$), whereas partial CG in feces was greatest for CG, intermediate for BCG, and least with BG ($P < 0.01$).

Table 5. Relative proportions of whole kernels, partial kernels, and fiber in feces from steers fed diets composed of barley silage (BS) or corn silage (CS) with dry-rolled barley (BG), corn (CG), or an equal blend of barley and corn grain (BCG).

Component	BS			CS			P			
	BG	CG	BCG	BG	CG	BCG	SEM	Silage	Grain	S × G
Fecal weight (g 250 mL^{-1})	230.9	237.5	237.7	234.0	242.4	239.3	10.97	0.50	0.39	0.96
Particles retained[a] (g DM^{-1})	100.3z	76.7zy	84.9zy	70.2y	75.3y	72.9y	5.82	0.003	0.31	0.036
Whole barley (%)	15.6a	7.7b	11.3b	7.9a	NP	4.9b	1.76	<0.001	<0.001	0.55
Partial barley (%)	1.9	0.6	1.1	2.2	NP	0.9	0.94	0.91	0.06	0.60
Whole corn (%)	NP	0.0	0.2	0.9	0.6	0.2	0.38	0.43	0.51	0.43
Partial corn (%)	NP	22.5a	11.8b	5.0c	30.4a	25.8b	3.38	0.006	<0.001	0.38
Total fines (%)	82.3a	68.9b	75.2b	83.8b	66.4b	67.8b	6.25	0.35	0.001	0.47

Note: SEM, standard error of mean; S × G, silage × grain interaction; NP, treatments where the dependent variable was not present based on analysis and the treatment structure. Means within a column not sharing a common lowercase letter (a, b, or c) differ significantly at the $P < 0.05$ level for the cereal grain effect. Means within a column not sharing a common lowercase letter (x, y, or z) differ significantly at the $P < 0.05$ level for the $S × G$ interaction. The standard error for the interaction are reported.

[a]Particles were wet sieved using a 1.18 mm sieve.

Discussion

In the present study, our objective was to evaluate whether interactions occurred among the cereal silage sources and the cereal grain sources when using corn and barley as the principle cereal silage and cereal grain for backgrounding cattle. Although BS and BG have less starch and greater CP than CS and CG (NASEM 2016), the rates and extents of digestion for barley starch and protein are more rapid than corn (Herrera-Saldana et al. 1990). Moreover, there is limited research evaluating short-season corn as a forage source and when evaluating silage × grain and grain source interactions for growing cattle. That said, previous research in finishing cattle has demonstrated that blending rapidly fermentable starch with starch sources that have a slower rate of fermentation may optimize ruminal fermentation (Vander Pol et al. 2009) leading to positive associative effects on growth performance. For example, Stock et al. (1987) and Huck et al. (1998) reported that the greatest positive associative effects were observed in finishing diets when high-moisture corn was included with dry-rolled corn at a ratio of 75:25. Additionally, when using combinations of high-moisture corn and dry-rolled wheat, positive associative responses for feed conversion were reported with a ratio of 25:75. In the current study, both the CG and CS had numerically greater starch concentrations compared with BG and BS, and given that both CG and BG were dry-rolled, it could be expected that rates and extents of ruminal fermentation differed among the grain sources (Campling 1991). However, we did not detect any additive effects when feeding combinations of BG and CG suggesting that when dry-rolled and included at low levels, differences in fermentation rates are not sufficient to detect associative effects for barley and corn. In addition, the detection of positive associative effects in finishing studies may be in part due to the greater dietary inclusion rates of cereal grain than when compared with diets for backgrounding

cattle or diets for dairy cattle, thereby increasing the magnitude of the response. In support of this concept, including ryegrass or CS with a highly fermentable carbohydrate source (ground corn, steam-flaked corn, or hominy feed) in diets for dairy cattle did not yield positive additive effects for DMI, milk yield, or milk composition (Cooke et al. 2009). Moreover, there were no detectable interactions among the cereal silage sources and cereal grain sources, suggesting that the digestion of the starch source from the silage may not interact with the cereal grain source at the inclusion levels used in the present study.

Effects of silage source

There is little data available on the use of short-season corn and its effects on growth performance of backgrounding cattle (Chibisa and Beauchemin 2018). In the present study, we observed that cattle fed CS had greater DMI and greater BW at the end of the study. In contrast, Chibisa and Beauchemin (2018) reported that short-season CS reduced DMI for backgrounding steers when included at an equivalent dietary DM concentration as BS. Consequently, they also reported lower ADG and G:F for steers fed CS than BS. However, the CS in Chibisa and Beauchemin (2018) contained greater concentrations of NDF than BS, and the authors speculated that the reduction in DMI may be due to constraints related to NDF intake. Corn silage in the current study had lower NDF and greater starch than BS supporting the concept that forages with lower NDF concentration may stimulate DMI for growing cattle (Fox et al. 1992; Allen 2000). The increased DMI for CS-fed cattle relative to BS-fed cattle may also be in response to greater digestibility, as estimated by NIR spectroscopy of dry feces and established calibrations (Jancewicz et al. 2016), thereby reducing the fill effect of NDF (Oba and Allen 1999).

Kernel processing of CS at harvest cracks the kernels allowing for greater starch utilization relative to

unprocessed CS (Cooke and Bernard 2005). In the current study, diets containing CS had greater starch digestibility compared with those fed BS. In contrast, there are currently no recommendations promoting kernel processing of BS; although, one study demonstrated improved starch digestibility when BS was processed using a 1 mm roller gap at the time of ensiling (Eun et al. 2004). Although there is little data available evaluating kernel processing of BS, a novel aspect of this study was that we evaluated the appearance of kernels in the feces in addition to fecal starch concentrations. These data further support increased starch digestibility for CS relative to BS as the use of BS increased the weight of particles retained on a 1.18 mm sieve and the appearance of whole barley kernels in feces relative to cattle fed CS. Moreover, the use of CG reduced but did not eliminate the appearance of barley kernels in the feces of cattle fed BS indicating that the hull and pericarp of the barley kernels in the silage were not damaged consistently. Though there was greater appearance of whole kernels in the feces, the fecal starch concentration was only numerically greater, suggesting that some of the kernels may be at least partially digested, as observed by Loerch et al. (2006). Thus, the data indicate that for backgrounding cattle, BS may contribute to the appearance of the barley kernels in feces and strategies to enhance kernel processing may improve starch digestibility. The use of a kernel processor for BS may be warranted to enhance starch digestibility, but it must be evaluated in relation to the added fuel and time required at harvest to chop and process the silage.

Although initial BW was greater for CS steers than BS, the differences were interpreted not to have biological significance as the mean BW differed by 700 g. However, as a consequence of greater DMI and greater nutrient digestibility for CS-fed cattle, final BW of the CS-fed steers was 8.4 kg greater than for steers fed BS. Despite greater final BW, ADG, G:F, and the predicted NE_m and NE_g did not differ among steers fed BS vs. CS. These data are interpreted to suggest that despite greater digestibility, use of short-season corn is not likely to improve G:F due to increased DMI and no differences for ADG.

Cereal grain source

Although dietary starch numerically increased with increasing CG, there was no stimulatory effect on DMI, ADG, or G:F. A study conducted by Koenig and Beauchemin (2005) comparing BG and CG in a finishing diet found greater DMI, ADG, and G:F for BG treatments compared with CG treatments with no added protein. Another study by Beauchemin et al. (1997) found greater DMI and ADG for BG compared with CG, but G:F was greater for the CG diets compared with the BG diets. In addition, Johnson et al. (2020) also reported greater DMI for corn-based finishing diets. In a review, Owens et al. (1997) found no differences between CG or BG on DMI,

ADG, and G:F. The lack of differences detected between CG and BG in the present study seems to be consistent with the previous studies, though this may be due to the low inclusion rate of grain in the present study compared with the high inclusion rates for the previous studies.

The cereal grains in this study were both dry rolled to avoid a bias of processing method. Processing for CG in the present study was targeted to achieve a processing index such that 5% of the particles passed through a 1 mm sieve as an approach to minimize production of fine particles. Retrospectively, this resulted in dry-rolled CG with a processing index of 83%, which is a value greater than the 70% typical of dry-rolled CG (Zinn et al. 2002). It is likely that the severity of processing was insufficient to optimize the surface area available for microbial attachment and digestion when considering the starch and protein matrix in the endosperm (McAllister and Cheng 1996). We were unable to determine the concentrations of floury and vitreous endosperm, but past research has shown that for flint corn, dry rolling is likely not sufficient to maximize starch digestibility (Plascencia and Zinn 1996; Yu et al. 1998). In contrast, the BG was dry rolled to achieve a processing index of 66%, as Koenig et al. (2003) reported that more extensively processed grain (86% vs. 61%) increased total tract starch digestibility. Past research has suggested a processing index ranging from 65% to 75% for BG (Beauchemin et al. 2001), and despite being extensively processed, fecal starch concentrations in the present study (averaging 8.6% DM, 14.0% DM, and 16.9% DM for BG, BCG, and CG, respectively) were still greater than reported in other research. Jancewicz et al. (2017a) reported fecal starch concentrations of 2.24% for backgrounding cattle in commercial feedlots, with greater fecal starch concentrations having a negative impact on G:F. Although the high fecal starch concentrations can be related to the lower starch digestibility for CG and the less severe processing of CG than BG, even with a processing index of 66% for BG, fecal starch averaged 8.6% and we detected appearance of whole-barley in feces from cattle. The appearance of whole-barley in feces is likely explained by variable kernel size and that some kernels may have passed through the rollers without being processed. In contrast, there was nearly no whole-corn present in feces suggesting that while the processing severity was low, nearly all kernels were cracked. In addition, our study has shown that some of the starch appearing in feces appears to be caused by inadequate starch digestibility in BS and CS at least based on whole kernel and partial kernel appearance, respectively.

Conclusion

The use of CS or BS with BG, CG, or BCG did not interact to affect performance of backgrounding cattle. That said, feeding CS to backgrounding cattle may increase

DMI, final BW, and nutrient digestibility as compared with BS, whereas dry-rolled BG may increase nutrient digestibility and reduce fecal starch when compared against diets with CG or BCG. Thus, it appears that the silage source independently affects the performance of backgrounding cattle, and the data in this study are interpreted to suggest that CS may increase DMI and final BW without affecting G:F. Furthermore, feeding dry-rolled BG may enhance apparent nutrient digestibility, but it does not appear to influence DMI, ADG, or G:F, suggesting that, in backgrounding diets and when dry-rolled, CG and BG do not differ in their effectiveness despite greater starch concentration for CG.

Acknowledgements

References

Allen, M.S. 2000. Effects of diet on short-term regulation of feed intake by lactating dairy cattle. J. Dairy Sci. **83**: 1598–1624. doi:10.3168/jds.S0022-0302(00)75030-2.

Beauchemin, K.A., Jones, S.D.M., Rode, L.M., and Sewalt, V.J.H. 1997. Effects of fibrolytic enzymes in corn or barley diets on performance and carcass characteristics of feedlot cattle. Can. J. Anim. Sci. **77**: 645–653. doi:10.4141/A97-050.

Beauchemin, K.A., Yang, W.Z., and Rode, L.M. 2001. Effects of barley grain processing on the site and extent of digestion of beef feedlot finishing diets. J. Anim. Sci. **79**: 1925–1936. doi:10.2527/2001.7971925x.

Campling, R.C. 1991. Processing cereal grains for cattle — a review. Livest. Prod. Sci. **28**: 223–234. doi:10.1016/0301-6226(91)90144-F.

Chibisa, G.E., and Beauchemin, K.A. 2018. Effects of feeding corn silage from short-season hybrids and extending the back-grounding period on production performance and carcass traits of beef cattle. J. Anim. Sci. **96**: 2490–2503. doi:10.1093/jas/sky099.

Cooke, K.M., and Bernard, J.K. 2005. Effect of length of cut and kernel processing on use of corn silage by lactating dairy cows. J. Dairy Sci. **88**: 310–316. doi:10.3168/jds.S0022-0302(05)72689-8.

Cooke, K.M., Bernard, J.K., and West, J.W. 2009. Performance of lactating dairy cows fed ryegrass silage and corn silage with ground corn, steam-flaked corn, or hominy feed. J. Dairy Sci. **92**: 1117–1123. doi:10.3168/jds.2008-1481.

Eun, J.S., Beauchemin, K.A., Hong, S.H., and Yang, W.Z. 2004. Effects of mechanical processing on the nutritive value of barley silage for lactating dairy cows. J. Dairy Sci. **87**: 4170–4177. doi:10.3168/jds.S0022-0302(04)73560-2.

Fox, D.G., Sniffen, C.J., O'Connor, J.D., Russell, J.B., and Van Soest, P.J. 1992. A net carbohydrate and protein system for evaluating cattle diets: III. Cattle requirements and diet adequacy. J. Anim. Sci. **70**: 3578–3596. doi:10.2527/1992.70113578x.

Government of Saskatchewan. 2016. Saskatchewan heat unit maps. [Online]. Available from http://publications.gov.sk.ca/documents/20/83796-corn heat units maps.pdf [7 Jan. 2020].

Hedrick, H.B., Paterson, J.A., Matches, A.G., Thomas, J.D., Morrow, R.E., Stringer, W.G., and Lipsey, R.J. 1983. Carcass and palatability characteristics of beef produced on pasture, corn silage and corn grain. J. Anim. Sci. **57**: 791–801. doi:10.2527/jas1983.574791x.

Herrera-Saldana, R.E., Huber, J.T., and Poore, M.H. 1990. Dry matter, crude protein, and starch degradability of five cereal grains. J. Dairy Sci. **73**: 2386–2393. doi:10.3168/jds.S0022-0302(90)78922-9.

Huck, G.L., Kreikemeier, K.K., Kuhl, G.L., Eck, T.P., and Bolsen, K.K. 1998. Effects of feeding combinations of steam-flaked grain sorghum and steam-flaked, high-moisture, or dry-rolled corn on growth performance and carcass characteristics in feedlot cattle. J. Anim. Sci. **76**: 2984–2990. doi:10.2527/1998.76122984x.

Jancewicz, L.J., Penner, G.B., Swift, M.L., McKinnon, J.J., Waldner, C.L., and McAllister, T.A. 2016. Characterization of the variation in the daily excretion of faecal constituents and digestibility predictions in beef cattle fed feedlot diets using near-infrared spectroscopy. Can. J. Anim. Sci. **96**: 532–549. doi:10.1139/cjas-2015-0193.

Jancewicz, L.J., Penner, G.B., Swift, M.L., Waldner, C.L., Koenig, K.M., Beauchemin, K.A., and McAllister, T.A. 2017*a*. Predicting fecal nutrient concentrations and digestibilities and growth performance in feedlot cattle by near-infrared spectroscopy. J. Anim. Sci. **95**: 455–474. doi:10.2527/jas2016.0876.

Jancewicz, L.J., Swift, M.L., Penner, G.B., Beauchemin, K.A., Koenig, K.M., Chibisa, G.E., et al. 2017*b*. Development of near-infrared spectroscopy calibrations to estimate fecal composition and nutrient digestibility in beef cattle. Can. J. Anim. Sci. **97**: 51–64. doi:10.1139/cjas-2016-0107.

Johnson, J.A., Sutherland, B.D., McKinnon, J.J., McAllister, T.A., and Penner, G.B. 2020. Use of barley or corn silage when fed with barley, corn, or a blend of barley and corn on growth performance, nutrient utilization, and carcass characteristics of finishing beef cattle. Transl. Anim. Sci. **4**: 129–140. doi:10.1093/tas/txz168.

Koenig, K.M., and Beauchemin, K.A. 2005. Barley- versus protein-supplemented corn-based diets for feedlot cattle evaluated using the NRC and CNCPS beef models. Can. J. Anim. Sci. **85**: 377–388. doi:10.4141/A04-029.

Koenig, K.M., Beauchemin, K.A., and Rode, L.M. 2003. Effect of grain processing and silage on microbial protein synthesis and nutrient digestibility in beef cattle fed barley-based diets. J. Anim. Sci. **81**: 1057–1067. doi:10.2527/2003.8141057x.

Lardner, H.A., Pearce, L., and Damiran, D. 2017. Evaluation of low heat unit corn hybrids compared to barley for forage yield and quality on the Canadian prairies. Sustain. Agric. Res. **6**: 90. doi:10.5539/sar.v6n1p90.

Loerch, S.C., Gorocica-Buenfil, M., and Wooster, O.H. 2006. Advantages and disadvantages of feeding whole shelled corn. pp. 73–80. [Online]. Available from http://beefextension.com/proceedings/cattle_grains06/06-10.pdf [16 Jan. 2020].

McAllister, T.A., and Cheng, K.J. 1996. Microbial strategies in the ruminal digestion of cereal grains. Anim. Feed Sci. Technol. **62**: 29–36. doi:10.1016/S0377-8401(96)01003-6.

Miorin, R.L., Holtshausen, L., Baron, V., and Beauchemin, K.A. 2018. In situ rumen degradation of kernels from short-season corn silage hybrids as affected by processing. Transl. Anim. Sci. **2**: 428–438. doi:10.1093/tas/txy084. PMID:32704725.

National Academies of Sciences, Engineering and Medicine (NASEM). 2016. Nutrient requirements of beef cattle. 8th

rev. ed. The National Academies Press, Washington, DC, USA. doi:10.17226/19014.

Oba, M., and Allen, M.S. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J. Dairy Sci. **82**: 589–596. doi:10.3168/jds.S0022-0302(99)75271-9.

Owens, F.N., Secrist, D.S., Hill, W.J., and Gill, D.R. 1997. The effect of grain source and grain processing on performance of feedlot cattle: a review. J. Anim. Sci. **75**: 868–879. doi:10.2527/1997.753868x.

Pelletier, N., Pirog, R., and Rasmussen, R. 2010. Comparative life cycle environmental impacts of three beef production strategies in the Upper Midwestern United States. Agric. Syst. **103**: 380–389. doi:10.1016/j.agsy.2010.03.009.

Plascencia, A., and Zinn, R.A. 1996. Influence of flake density on the feeding value of steam-processed corn in diets for lactating cows. J. Anim. Sci. **74**: 310–316. doi:10.2527/1996.742310x.

Rosser, C.L., Górka, P., Beattie, A.D., Block, H.C., McKinnon, J.J., Lardner, H.A., and Penner, G.B. 2013. Effect of maturity at harvest on yield, chemical composition, and in situ degradability for annual cereals used for swath grazing. J. Anim. Sci. **91**: 3815–3826. doi:10.2527/jas.2012-5677.

Stock, R.A., Brink, D.R., Brandt, R.T., Merrill, J.K., and Smith, K.K. 1987. Feeding combinations of high moisture corn and dry corn to finishing cattle. J. Anim. Sci. **65**: 282–289. doi:10.2527/jas1987.651282x.

Tothi, R., Lund, P., Weisbjerg, M.R., and Hvelplund, T. 2003. Effect of expander processing on fractional rate of maize and barley starch degradation in the rumen of dairy cows estimated using rumen evacuation and in situ techniques. Anim. Feed Sci. Technol. **104**: 71–94. doi:10.1016/S0377-8401(02)00292-4.

Vander Pol, K.J., Luebbe, M.K., Crawford, G.I., Erickson, G.E., and Klopfenstein, T.J. 2009. Performance and digestibility characteristics of finishing diets containing distillers grains, composites of corn processing coproducts, or supplemental corn oil. J. Anim. Sci. **87**: 639–652. doi:10.2527/jas.2008-1036.

Yu, P., Huber, J.T., Sanotos, F.A., Simas, J.M., and Theurer, C.B. 1998. Effects of ground, steam-flaked, and steam-rolled corn grains on performance of lactating cows. J. Dairy Sci. **81**: 777–783. doi:10.2168/jds.S0022-0302(98)75634-6.

Zinn, R.A., and Shen, Y. 1998. An evaluation of ruminally degradable intake protein and metabolizable amino acid requirements of feedlot calves. J. Anim. Sci. **76**: 1280–1289. doi:10.2527/1998.7651280x.

Zinn, R.A., Owens, F.N., and Ware, R.A. 2002. Flaking corn: processing mechanics, quality standards, and impacts on energy availability and performance of feedlot cattle. J. Anim. Sci. **80**: 1145–1156.