Effects of feeding corn silage from short-season hybrids and extending the backgrounding period on production performance and carcass traits of beef cattle

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ABSTRACT: Corn silage (CS) acreage in western Canada continues to expand with CS being used increasingly in feedlot cattle diets where barley silage (BS) previously was the main forage fed. Our study evaluated the effects of increasing the amounts of CS in backgrounding (BKGN) diets on performance of cattle by 1) replacing BS with early-maturing CS, 2) increasing the proportion of CS in the diet, and 3) extending the BKGN duration. A total of 160 steers (mean BW $\pm$ SD; 272 $\pm$ 22.4 kg) were used in a completely randomized design. Steers were assigned to 16 pens and fed BKGN diets (4 pens per diet) that contained 60% BS (DM basis; CON), 60% CS (60CS), 75% CS (75CS), or 90% CS (90CS) until reaching a mean pen BW of either 380 (SBKGN) or 430 $\pm$ 15 kg (LBKGN) with 2 pens per treatment. All steers were finished (FIN diet; 9% CS, 86% barley grain, and 5% supplement) to an equal-BW end point (700 $\pm$ 15 kg LW). During BKGN and FIN phases, DMI, ADG, and G:F were measured for all pens. Carcass data also were collected. No BKGN diet $\times$ duration interactions were statistically significant ($P \geq 0.412$) for most production measures. As dietary CS content was increased during BKGN, DMI and ADG decreased (quadratic; $P \leq 0.003$). There also was a tendency ($P = 0.078$)

for a decrease in G:F at the highest level of CS. As expected, LBKGN steers took longer (105 vs. 71 d; $P = 0.001$) than SBKGN steers to reach the BKGN target end weight. In addition, as a result of their heavier weight at the beginning of FIN, LBKGN steers also had a higher DMI (11.6 vs. 11.0 kg/d; $P = 0.045$) than SBKGN steers. However, no carryover effects ($P \geq 0.354$) of BKGN diet on DMI, ADG, and G:F were significant during the FIN phase. Similarly, the BKGN diet and duration had no effect ($P \geq 0.219$) on carcass traits including HCW, dressing percentage, and quality grade. However, we detected an interaction between BKGN diet and duration on backfat thickness ($P = 0.009$); SBKGN steers that were fed 75CS during BKGN accumulated more backfat during FIN than LBKGN steers that were fed 75CS during BKGN, and because they were lighter at the beginning of FIN they took longer to reach 700 kg BW, their end point. In conclusion, dietary inclusion of CS (up to 90% of diet DM) in place of BS and extending the BKGN period had marginal effects on FIN performance or carcass traits in our study. Therefore, beef producers can make extensive use of early-maturing CS in growing cattle diets without compromising animal performance or carcass quality.

Key words: backgrounding, barley silage, corn silage, finishing, production performance

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J. Anim. Sci. 2018.96:2490–2503
doi: 10.1093/jas/sky099

INTRODUCTION

Historically, corn silage (CS) has found limited use in backgrounding (BKGN) cattle diets in western Canada because of the shortage of heat units (CHU) and moisture. However, in recent

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Received November 20, 2017.
Accepted March 14, 2018.

years, a trend for increases in CHU and growing season precipitation (Nadler and Bullock, 2011) and recent availability of early-maturing corn hybrids has increased use of CS where barley silage (BS) previously was the main forage used. Seed companies have developed short-season hybrids that mature in fewer days with high grain yield and optimum DM content for ensiling. Choice of forage for beef producers is influenced by the cost of forage production, yield potential, and nutritive value. Corn has a higher cost of production (50%) and yield potential (32%) than barley (Baron et al., 2014a, 2014b). However, information on the nutritive value of early-maturing CS is lacking (Opsit et al., 2013).

Earlier studies (Mowat and Slumskie, 1971; Burgess et al., 1973) have reported that digestible energy content is greater for CS than BS; this increased ADG and feed efficiency or milk production in beef and dairy cattle. Recently, Baron et al. (2014b) noted that early-maturing CS can contain up to 30% starch, a value much greater than for BS. Thus, substitution of early-maturing CS for BS may make it possible to increase the level of forage in BKGn diets through increasing the forage proportion by replacing grain and extending the BKGn period. However, substitution of CS for BS and increased feeding of CS may not prove viable if finishing (FIN) performance is compromised. We hypothesized that early-maturing CS could replace BS in BKGn diets, and because of its greater starch content, the dietary proportion of CS could be increased and the duration of the BKGn phase could be extended without compromising animal performance or carcass quality. Our objective was to evaluate the effects of feeding various amounts of early-maturing CS during BKGn and extending the duration of BKGn on FIN cattle performance.

MATERIALS AND METHODS

Animal use for this experiment was preapproved (protocol # 1421) by the Institutional Animal Care and Use Committee of the Lethbridge Research and Development Centre, Lethbridge, AB, and followed the guidelines of the Canadian Council of Animal Care (2009).

Silage Production

Corn (*Zea mays* L., hybrid 39D95, 2175 CHU rating; Pioneer Hi-Bred Ltd, Chatham, ON, Canada) used for this study was planted in May of

2014 on a commercial farm near Lethbridge, AB, Canada. The long-term mean CHU received (from seeding to grain harvest) for this site is 2448, but the growing year of 2014 was below normal at 2205 CHU. Harvest (September of 2014, before frost) was at one-half to two-thirds milk line maturity (32% whole plant DM; 50% kernel DM). A John Deere 7780 forage harvester (John Deere, Moline, IL) with an 8-row header was used to chop the forage to a theoretical length of 1.3 cm. During harvest, a kernel processor was used and an inoculant (11CFT, Pioneer Hi-Bred Ltd) was applied during ensiling. Barley (*Hordeum vulgare* L.; Agri-Core United, Winnipeg, MB, Canada) was seeded near Lethbridge in May of 2014. Swathing (MacDon 205 swather with 89 cm header; MacDon Inc., Kansas City, MO) was carried out in July of 2014 at the soft dough stage of grain maturity (35% to 38% DM). The chopped forages were delivered by trucks, ensiled in concrete-walled bunker silos, packed to exclude oxygen using a tractor (9460R, John Deere, Moline, IL), and the silos were covered with oxygen-limiting plastic film and tires.

Animals and Experimental Design

A total of 144 Continental crossbred steers (mean $\pm$ SD, 272 $\pm$ 22.4 kg incoming BW) were sourced commercially. Upon arrival at the Lethbridge Research and Development Centre, steers were ear tagged, branded, implanted (Component TE-S with Tylan, Elanco Animal Health, Guelph, ON, Canada) and provided a barley-based receiving total mixed ration (TMR; 80% barley silage and 20% concentrate on a DM basis) until they were allotted randomly to the study pens. An additional 16 steers (293 $\pm$ 18.7 kg BW) from a previous study also were used after being fitted with ruminal cannulas (model 9C; Bar Diamond, Inc., Parma, ID) approximately 90 d prior to the start of the study. At the beginning of the study, the 160 steers were blocked by BW (light or heavy animals; 258 $\pm$ 18.1 and 291 $\pm$ 13.9 kg, respectively) and assigned randomly to 1 of 4 dietary treatments. Steers were allocated to 16 pens (4 pens per treatment, 10 steers per pen). Each pen measured 21 $\times$ 27 m that provided 12.6 m² of pen space for each steer, a stocking density comparable to commercial feedlot standards. Eight of the 16 pens contained 2 feeding troughs that were equipped with an electronic monitoring system (GrowSafe Systems, Airdrie, AB, Canada) that automatically recorded feeding behavior. Each of the 4 treatments was offered in 2 of the 8 GrowSafe pens. In addition,

the 16 cannulated steers were assigned equally among the 8 GrowSafe pens (2 cannulated steers per pen). Performance data for the cannulated cattle were included in the performance analysis, but their rumen fermentation and feeding behavior data will be reported separately.

Dietary Treatments

On day 0 of the study, steers were allocated randomly and transitioned systematically over 16 d to 1 of 4 experimental treatments: 1) a standard BKGN diet consisting of 60% barley silage (control; **CON**), 2) 60% corn silage (60CS), 3) 75% corn silage (75CS), and 4) 90% corn silage (90CS) on a DM basis. The chemical composition of the 2 silages is presented in [Table 1](#). Increasing the proportion of CS in the diet was achieved by decreasing the proportion of barley grain ([Table 2](#)). Although statistical analysis was not conducted, silages and BKGN diets differed numerically in composition. Despite the starch content of BS being 6.6 percentage units lower than CS (23.9 vs. average of 30.5% of diet DM; [Table 1](#)), the assayed starch content of the barley-based CON and 60CS diets were comparable (34.6 vs. 34.9%; [Table 2](#)). Starch content of the 75CS and 90CS diets were numerically lower than the CON and 60CS diets due to replacement of barley grain with CS. The NDF content averaged about 3 percentage units greater for CS than BS ([Table 1](#)); therefore, an increase

in CS inclusion level resulted in an increase in the NDF and indigestible NDF content of the diets ([Table 2](#)). The proportion of large (>19 mm) and medium-sized (8 to 19 mm) particles increased as the amount of CS in the diet increased ([Table 2](#)). This altered the amounts and composition of orts as discussed later.

Each of the 4 pens for each treatment also were randomly designated to either a short (**SBKGN**; 2 pens per treatment) or a long (**LBKGN**; 2 pens per treatment) BKGN phase. Starting on day 17, all steers were fed the BKGN diets until the transition (**TRANS**) to a common FIN diet that consisted of 9% CS, 86% dry-rolled barley grain, and 5% supplement on a DM basis ([Table 3](#)). As expected, the starch content of the FIN diet was high (56.1% of diet DM) due to the high inclusion level of barley grain (89% of diet DM). Four steps were used during TRANS to the FIN ration. For SBKGN steers, the BKGN phase ended when the average pen BW was 380 ± 15 kg. In contrast, the LBKGN steers were maintained on their BKGN diets until they reached a mean pen BW of 430 ± 15 kg when they were transitioned to the FIN diet. All diets were prepared daily as a TMR that was delivered (Beck 220 Mixer; Beck Implement Inc., Elgin, MN) once daily at 0830 h for free choice intake (5% orts). Diets were balanced to meet or exceed the dietary requirements of BKGN and FIN feedlot cattle specified in [NRC \(2000\)](#) guidelines. Monensin (28 mg/kg) was included in all diets, but no tylosin

Table 1. Chemical composition and ensiling characteristics of barley and corn silage

Item (% of DM, unless otherwise noted)	Experimental silage ^a		
	Barley (BKGN)	Corn (BKGN)	Corn (FIN)
Chemical composition ^b			
DM (%)	36.8 $\pm$ 3.17	34.2 $\pm$ 3.29	40.4 $\pm$ 1.85
OM	92.5 $\pm$ 0.26	95.1 $\pm$ 0.33	95.6 $\pm$ 0.29
CP	10.7 $\pm$ 0.69	8.5 $\pm$ 0.79	9.1 $\pm$ 0.28
ADF	27.5 $\pm$ 0.90	27.8 $\pm$ 1.19	24.5 $\pm$ 1.42
NDF	43.5 $\pm$ 0.75	49.1 $\pm$ 5.53	43.6 $\pm$ 2.88
Starch	23.9 $\pm$ 1.82	28.2 $\pm$ 2.35	32.7 $\pm$ 1.74
Ensiling characteristics ^b			
Total VFA	8.11	6.37	8.21
Lactic acid	5.50	3.05	5.00
Acetic acid	2.61	3.32	3.21
Propionic acid	0.11	0.13	0.11
Butyric acid	ND ^c	ND	ND
Isobutyric acid	ND	ND	ND
1,2-Propanediol	0.73	0.40	0.42
Ethanol soluble carbohydrates	2.10	1.25	0.90

^aBKGN = backgrounding phase; FIN = finishing phase.

^bMeasured on pooled samples collected during BKGN and FIN.

^cND = not detected.

Table 2. Ingredient and chemical composition, and particle size distribution of the backgrounding diets

Item	Diet ^a			
	CON	60CS	75CS	90CS
Ingredient, % of DM				
Barley silage	60	0	0	0
Corn silage	0	60	75	90
Barley grain, dry-rolled	30	30	15	0
Supplement				
Barley grain	5.9	2.5	1.7	0.9
Canola meal	2.6	5.6	6.4	7.3
Limestone	1.0	1.0	0.8	0.7
Urea	0.320	0.700	0.800	0.900
Salt	0.110	0.110	0.110	0.110
Canola oil	0.050	0.050	0.050	0.050
Molasses	0.050	0.050	0.050	0.050
Feedlot premix ^b	0.050	0.050	0.050	0.050
Rumensin premix ^c	0.014	0.014	0.014	0.014
Chemical analysis				
DM (%)	46.2 ± 1.84	45.7 ± 3.76	41.0 ± 3.32	37.4 ± 3.37
OM (% of DM)	93.4 ± 0.34	94.5 ± 0.44	94.4 ± 0.35	94.2 ± 0.66
Starch (% of DM)	34.6 ± 4.08	34.9 ± 2.67	31.4 ± 3.64	27.4 ± 2.45
NDF (% of DM)	33.9 ± 1.10	36.3 ± 0.73	41.0 ± 0.72	44.7 ± 1.17
Indigestible NDF (% of DM)	8.3 ± 0.17	10.5 ± 0.12	11.8 ± 0.42	13.1 ± 0.43
ADF (% of DM)	18.5 ± 1.20	19.9 ± 1.19	23.0 ± 0.97	26.8 ± 1.18
CP (% of DM)	13.1 ± 0.39	13.6 ± 0.77	13.3 ± 0.53	13.8 ± 0.76
Particle size (% of DM, as-is basis) ^d				
Large (>19 mm)	4.61 ± 0.819	5.11 ± 0.501	6.90 ± 1.216	8.08 ± 1.808
Medium (8 to 19 mm)	46.7 ± 2.35	51.6 ± 2.29	60.6 ± 3.20	66.8 ± 3.31
Fine (1.18 to 8 mm)	44.1 ± 2.28	37.8 ± 1.92	27.9 ± 2.17	21.4 ± 1.89
Bottom (<1.18 mm)	4.61 ± 0.524	5.45 ± 0.590	4.65 ± 0.998	3.64 ± 0.524

^aCON = 60% barley silage; 60CS = 60% corn silage; 75CS = 75% corn silage; 90CS = 90% corn silage.

^bFeedlot premix provided an additional 14 g/kg Ca, 103 mg/kg Zn, 26 mg/kg Cu, 47 mg/kg Mn, 1 mg/kg I, 0.50 mg/kg Se, 0.33 mg/kg Co, 17,187 IU/kg vitamin A, 859 IU/kg vitamin D₃, and 24 IU/kg vitamin E to the diet DM.

^cRumensin premix contained 200 g monensin/kg.

^dParticle size distribution of TMR measured using the Penn State Particle Separator (Kononoff et al., 2003).

was fed. Steers had free access to water throughout the study. Regardless of the length of the BKGN phase (SBKGN and LBKGN), all steers were finished to an equal-BW end point (700 ± 15 kg LW).

Dry Matter Determination and Feed Analysis

Fresh feed offered was recorded daily for each pen and orts were collected, weighed, and subsampled weekly throughout the study. Following subsampling, the remainder of the orts was discarded. Total mixed ration and ingredient (CS, BS, barley grain, and supplement) samples were collected once each week. All samples were analyzed for DM by oven drying at 55 °C for 48 h; DMI was determined weekly for each diet and pen. Weekly silage DM content was used to adjust the forage inclusion level (as-fed basis) if DM deviated by >3% from the mean. A 1-kg subsample of the weekly TMR and orts samples was used to determine particle

distribution using the Penn State Particle Separator as described by Kononoff et al. (2003).

At the end of the study, another 1-kg subsample of the weekly feed samples was oven-dried (55 °C for 48 h) and sequentially ground through a 4-mm (cutter mill) and 1-mm screen (Wiley mill, standard model 4, Arthur H. Thomas Co., Philadelphia, PA) for subsequent chemical analysis. Ground feed samples were analyzed for DM (AOAC, 2005; method 930.15), ash (AOAC, 2005; method 942.05), ADF (AOAC, 2005; method 973.18), and NDF (Mertens, 2002; with amylase and sodium sulfite). The TMR samples were analyzed also for indigestible NDF according to Ahvenjärvi et al. (2000). Briefly, 3.0 g samples were weighed into 5- × 10-cm nylon mesh bags (6-µm pore size; part no. 03-6/5, Sefar America Inc., Depew, NY) before being incubated for 288 h in the rumen of a ruminally cannulated cow. Following incubation, bags were rinsed in water for 30 min and analyzed for NDF (Mertens,

Table 3. Ingredient and chemical composition of the finishing phase diet

Item	Diet
Ingredient, % of DM	
Corn silage	9
Barley grain, dry-rolled	86
Supplement	
Barley grain	3.0
Limestone	1.25
Canola meal	0.30
Urea	0.038
Salt	0.250
Canola oil	0.050
Molasses	0.050
Feedlot premix ^a	0.050
Rumensin premix ^b	0.014
Vitamin E (500,000 IU/kg)	0.006
Chemical analysis	
DM (%)	81.7 ± 2.09
OM (% of DM)	95.8 ± 1.14
Starch (% of DM)	56.1 ± 4.37
NDF (% of DM)	24.2 ± 3.70
ADF (% of DM)	8.7 ± 1.62
CP (% of DM)	11.3 ± 0.69

^aFeedlot premix provided an additional 14 g/kg Ca, 103 mg/kg Zn, 26 mg/kg Cu, 47 mg/kg Mn, 1 mg/kg I, 0.50 mg/kg Se, 0.33 mg/kg Co, 17,187 IU/kg vitamin A, 859 IU/kg vitamin D₃, and 24 IU/kg vitamin E to the diet DM.

^bRumensin premix contained 200 g monensin/kg.

2002). Prior to CP (N × 6.25) and starch analyses, samples (ground through 1-mm screen) were pulverized using a ball mill (Mixer Mill MM2000; Retsch, Haan, Germany). Flash combustion with gas chromatography and thermal conductivity detection (Carlo Erba Instruments, Milan, Italy) were used to quantify total N. An enzymatic method that involved hydrolysis of starch using amylase, reaction of the resultant free glucose with glucose oxidase/peroxidase (No. P7119, Sigma, St. Louis, MO) and dianisidine dihydrochloride, with measurement of absorbance at 540 nm using a plate reader (SpectraMax 190, Molecular Devices Corp., Sunnyvale, CA) was used to measure total starch.

Growth Performance and Carcass Quality Determination

Steers were weighed on 2 consecutive days prior to the start (initial BW) and at the end of BKGN, and at the start and end of FIN (final BW). Steers were weighed also every 21 d during the study. To account for gut fill, BW are reported as shrunk BW basis (BW × 0.96). Average daily gain was calculated by dividing the gain in shrunk BW by the number of days fed. Feed efficiency (G:F) was calculated by

dividing ADG by DMI. Dietary NE_m content of both BKGN and FIN diets was estimated from performance and feed intake data as described by Zinn et al. (2002) using the formula of retained energy for large-framed yearling steers (NRC, 2000):

$$EG = 0.0493 \times [MW \times (478 / 650)]^{0.75} \times ADG^{1.097}$$

where EG = energy gained (retained energy; Mcal/d) and MW = average shrunk BW (kg) for the feeding period [(initial BW × 0.96 + final BW × 0.96)/2]. The NE_g (Mcal/kg) was calculated from NE_m (Mcal/kg) assuming NE_g = 0.877 NE_m - 0.41 as described by Zinn and Shen (1998) and Zinn et al. (2002).

At the end of the study, the cannulated steers (*n* = 16) were retained for use in other studies. However, all intact steers (*n* = 144) were weighed and transported to a commercial abattoir. Hot carcass weight, dressing percentage, backfat thickness, rib eye area, saleable meat yield, and quality grade were determined by qualified graders. Saleable meat yield (%) was estimated using the length, width, and fat cover of the rib eye muscle between the 11th and 12th rib; lean yield = 57.96 - 0.027 × (carcass weight) + 0.202 × (rib eye area) - 0.703 × (back fat thickness) as described by Basarab et al. (2003). Assessment of liver abscesses was conducted using the Elanco system; 0 = no abscesses, A- = 1 or 2 small abscesses or abscess scars, A = 2 to 4 well-organized abscesses < 2.5 cm diameter, and A+ = 1 or more large active abscesses > 2.5 cm diameter with inflammation of surrounding tissue as described by Brink et al. (1990).

Statistical Analysis

Data were analyzed as a completely randomized design using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Production performance data during BKGN was analyzed over the first 3 periods (up to 380 kg BW; SBKGN) and also for the entire BKGN period (up to 430 kg BW; LBKGN). Backgrounding diet (CON, 60CS, 75CS, or 90CS), duration of BKGN (SBKGN or LBKGN), and their interaction were included as fixed effects. The interaction term was removed from the model when *P* > 0.25. Pen was considered the experimental unit for DMI, ADG, G:F, and carcass measurements. The GLIMMIX procedure (SAS Inst. Inc., Cary, NC) was used to analyze data for meat quality grade and liver abscesses. Preplanned contrasts were used to evaluate differences between treatments and to test for linear and quadratic effects of level of CS in the diet.

Differences were declared significant at $P < 0.05$ with tendencies discussed at $0.05 \leq P \leq 0.10$. All reported values are least squares means.

RESULTS

Growth Performance During BKGN

By design, shrunk BW was similar across treatments at the beginning of the BKGN phase (Table 4). Final shrunk BW was also similar across diets during the first 3 periods of BKGN. However, dietary inclusion of CS in the BKGN diet resulted in a linear decrease ($P < 0.001$) in DMI and ADG. In addition, gain:feed was lower for steers fed the 75CS diet compared to the other 3 diets.

There was a diet $\times$ duration interaction ($P = 0.046$) for DMI during the entire BKGN period (Table 5). Dietary inclusion of CS resulted in a decrease in DMI; however, DMI was greater for LBKGN than SBKGN steers when fed the 75CS and 90CS diets, but not the 60CS diet (Fig. 1). However, there was no diet $\times$ duration interaction ($P \geq 0.412$) for the other measures of growth performance during BKGN (Table 5). Feeding either BS- or CS-based BKGN diets had no effect on either the BKGN duration ($P = 0.344$) or final (end of BKGN) shrunk BW ($P = 0.216$). However, increasing the dietary inclusion level of CS resulted in a decrease (quadratic; $P \leq 0.003$) in ADG, and a tendency ($P = 0.078$) for a decrease in G:F. There were no differences ($P = 0.934$) in calculated NE_g content of the diets.

As intended, the duration of BKGN was longer ($P = 0.001$) for LBKGN than SBKGN steers (105 vs. 71 d; Table 5). Similarly, LBKGN steers

consumed a greater amount of feed ($P < 0.01$) and were heavier at the end of the BKGN phase ($P < 0.01$) than SBKGN steers. Although ADG was greater (1.55 vs. 1.45 kg/d; $P = 0.021$) for LBKGN than SBKGN steers, there were no differences ($P = 0.222$) in G:F.

Orts from steers fed the CS diets contained a greater ($P < 0.001$) proportion of large particles compared to Orts from steers fed the CON diet (Table 6). In contrast, the proportion of fine particles < 8 mm was greater ($P < 0.001$) in Orts from cattle fed the CON than the CS diets. Although statistical analysis was not conducted, the chemical composition of Orts also differed numerically. Increasing the inclusion level of CS in the BKGN diets resulted in a decrease in the starch content, and an increase in the NDF content of Orts.

Growth Performance During Finishing

There was a BKGN diet $\times$ duration interaction ($P = 0.024$) on the duration of FIN (Table 7); when fed the 75CS diet during the BKGN period, SBKGN steers took longer to reach their FIN BW end point than LBKGN steers (Fig. 2). However, there were no BKGN diet $\times$ duration interactions ($P \geq 0.183$) for the other measures of growth performance during FIN (Table 7). Initial and final shrunk BW during FIN did not differ ($P \geq 0.426$) for steers fed either the CON, 60CS, 75CS, or 90CS diets during BKGN. Similarly, DMI, ADG, and G:F during the FIN phase did not differ ($P \geq 0.354$) for steers fed the different BKGN diets. Consequently, the calculated NE_g content did not differ ($P = 0.452$) among diets.

Table 4. Production performance of backgrounding cattle fed diets containing either barley silage (60%; DM basis) or increasing amounts of corn silage (60, 75, and 90%; DM basis) during the first 3 periods of backgrounding (up to 380 kg BW)

Item	Silage ^a				SEM	P-value		
	CON	60CS	75CS	90CS		Silage	Linear	Quadratic
n, animals (pen)	40 (4)	40 (4)	40 (4)	40 (4)	—	—	—	—
Shrunk BW ^b , kg								
Initial (day 1)	283	284	280	280	8.4	0.976	0.897	0.679
Final (day 63)	381	375	369	357	9.1	0.335	0.896	0.128
DM intake, kg/d	7.47 ^a	6.87 ^b	6.64 ^{bc}	6.36 ^c	0.118	<0.001	0.014	<0.001
ADG, kg/d	1.62 ^a	1.50 ^b	1.48 ^b	1.27 ^c	0.038	<0.001	0.334	<0.001
G:F	0.218 ^a	0.218 ^a	0.223 ^a	0.200 ^b	0.0052	0.039	0.303	0.233
NE_g ^c , Mcal/kg of diet	1.19	1.23	1.25	1.17	0.029	0.263	0.146	0.926

^aCON = 60% barley silage; 60CS = 60% corn silage; 75CS = 75% corn silage; 90CS = 90% corn silage.

^bShrunk BW calculated as 96% of liveweight (National Research Council, 2000).

^cCalculated based on performance (Zinn and Shen, 1998; Zinn et al., 2002).

^{a,b,c}Means for diet effect with different superscripts differ ($P < 0.05$).

Table 5. Production performance of backgrounding cattle fed diets containing either barley silage (60%; DM basis) or increasing amounts of corn silage (60, 75, and 90%; DM basis) for a short (up to 380 kg BW) or long duration (up to 430 kg BW)

Item	Silage ^a				SEM	Duration of BKG ^b		SEM	P-value ^c		
	CON	60CS	75CS	90CS		Short	Long		S	D	S × D
n, animals (pen)	40 (4)	40 (4)	40 (4)	40 (4)	–	80 (8)	80 (8)	–	–	–	–
Shrunk BW ^d , kg											
Initial (day 1)	283	284	280	280	9.9	284	279	7.0	0.985	0.600	0.970
Final (end of BKG ^b)	407	405	417	403	4.6	382 ^x	434 ^y	3.3	0.216	<0.001	0.494
Duration of BKG ^b , d	79	84	95	95	7	71 ^x	105 ^y	5	0.344	0.001	0.678
DMI, kg/d	7.64 ^a	7.16 ^b	7.13 ^b	6.77 ^c	0.065	6.86 ^x	7.49 ^y	0.046	<0.001	<0.001	0.046
ADG ^e , kg/d	1.64 ^a	1.49 ^{ab}	1.51 ^a	1.35 ^b	0.033	1.45 ^x	1.55 ^y	0.024	0.002	0.021	0.993
G:F	0.215	0.208	0.212	0.199	0.0039	0.211	0.206	0.0028	0.078	0.222	0.412
NE ^g , Mcal/kg of diet DM	1.20	1.21	1.24	1.20	0.026	1.21	1.21	0.018	0.676	0.934	0.501

^aCON = 60% barley silage; 60CS = 60% corn silage; 75CS = 75% corn silage; 90CS = 90% corn silage.

^bBKG^b = backgrounding.

^cS = backgrounding diet; D = duration of backgrounding; S × D = backgrounding diet × duration of the backgrounding.

^dShrunk BW calculated as 96% of liveweight (National Research Council, 2000).

^eQuadratic effect of CS level ($P = 0.096$).

^fQuadratic effect of CS level ($P < 0.05$).

^gCalculated based on performance (Zinn and Shen, 1998; Zinn et al., 2002).

^{a,b,c}Means for diet effect with different superscripts differ ($P < 0.05$).

^{x,y}Means for duration of backgrounding effect with different superscripts differ ($P < 0.05$).

As expected, the initial BW during FIN was greater ($P < 0.001$) for LBKGN than SBKGN steers (Table 7). However, by design, final BW was similar across diets. Dry matter intake was greater ($P = 0.045$) for LBKGN than SBKGN steers. However, there were no differences ($P \geq 0.476$) in ADG and G:F during the FIN phase between the SBKGN and LBKGN steers.

Dry Matter and NDF Intake Over the Entire Study

Although statistical analysis was not conducted, DMI as a percentage of BW was comparable across diets for the entire study (Fig. 3). However, NDF intake as a percentage of BW was higher for the steers fed the 75CS and 90CS diets compared to the CON and 60CS diets from period 2 to 4. Dry

Figure 1. Effects of backgrounding (BKG) diet and length of the BKG period on DMI during the BKG period. Backgrounding diets consisted of 60% barley silage (control; CON), or 60% corn silage (60CS), 75% corn silage (75CS), or 90% corn silage (90CS) on a DM basis. The BKG period ended when the average pen weight was either 380 or 430 ± 15 kg for steers backgrounded for a short (SBKGN) or extended period (LBKGN), respectively. Pooled SEM = 0.092. Diet, $P < 0.001$; duration of backgrounding, $P < 0.001$; diet × duration of backgrounding, $P = 0.046$.

Table 6. Chemical composition and particle size distribution of orts from backgrounding cattle fed diets containing either barley silage (60%; DM basis) or increasing amounts of corn silage (60, 75, and 90%; DM basis) for a short or long duration

	Silage ^a					Duration of BKG ^b				<i>P</i> -value ^c		
Item	CON	60CS	75CS	90CS	SEM	Short	Long	SEM	S	D	S × D	
<i>n</i> , animals (pen)	40 (4)	40 (4)	40 (4)	40 (4)	–	80 (8)	80 (8)	–	–	–	–	
Chemical analysis												
DM (%)	42.3 ± 4.60	37.6 ± 5.22	35.2 ± 6.09	35.7 ± 5.44	–	38.6 ± 6.25	36.8 ± 5.50	–	–	–	–	
OM (% of DM)	92.6 ± 0.01	95.2 ± 0.00	95.0 ± 0.01	93.1 ± 0.07	–	94.6 ± 0.01	93.4 ± 0.05	–	–	–	–	
Starch (% of DM)	34.9 ± 4.07	12.4 ± 3.22	12.9 ± 4.21	11.1 ± 3.51	–	19.2 ± 11.51	17.5 ± 10.48	–	–	–	–	
NDF (% of DM)	37.2 ± 3.23	63.9 ± 3.89	66.5 ± 5.88	69.9 ± 3.71	–	59.1 ± 14.47	59.7 ± 13.34	–	–	–	–	
ADF (% of DM)	17.7 ± 2.02	33.7 ± 2.04	35.7 ± 2.74	38.4 ± 4.00	–	30.8 ± 8.86	31.9 ± 8.48	–	–	–	–	
CP (% of DM)	12.5 ± 0.89	9.0 ± 0.75	9.0 ± 1.28	8.1 ± 1.02	–	9.6 ± 1.92	9.7 ± 2.05	–	–	–	–	
Particle size, % as-is												
Large (>19 mm) ^d	14.1 ^a	48.4 ^b	48.1 ^b	55.8 ^b	3.69	40.9	42.4	2.61	<0.001	0.698	0.449	
Medium (8 to 19 mm)	35.1	40.4	40.1	44.6	2.49	39.3	40.8	1.76	0.139	0.582	0.520	
Fine (1.18 to 0.8 mm) ^e	46.1 ^a	10.0 ^b	6.6 ^b	3.7 ^b	1.65	17.9	15.3	1.16	<0.001	0.153	0.503	
Bottom (<1.18 mm) ^f	4.66 ^a	1.19 ^b	0.68 ^{bc}	0.37 ^c	0.150	1.88	1.57	0.106	<0.001	0.071	0.366	

^aCON = 60% barley silage; 60CS = 60% corn silage; 75CS = 75% corn silage; 90CS = 90% corn silage.

^bBKG^b = backgrounding.

^cS = backgrounding diet; D = duration of backgrounding; S × D = backgrounding diet × duration of the backgrounding.

^dQuadratic effect of CS level ($P < 0.001$).

^eQuadratic effect of CS level ($P < 0.001$).

^fQuadratic effect of CS level ($P < 0.001$).

^{a,b,c}Means for diet effect with different superscripts differ ($P < 0.05$).

^{x,y}Means for duration of backgrounding effect with different superscripts differ ($P < 0.05$).

matter intake as a percentage of BW was comparable between SBKGⁿ and LBKGⁿ steers (Fig. 4). Neutral detergent fiber intake as a percentage of BW was lower for SBKGⁿ than LBKGⁿ steers during periods 5 and 6 of the study.

Carcass Characteristics

Hot carcass weight, dressing percentage, rib eye area, and meat yield were not affected ($P \geq 0.266$) by BKGⁿ diet or duration (Table 8). Similarly, neither BKGⁿ diet nor its duration had an effect ($P \geq 0.267$) on quality grade and liver scores. However, there was a BKGⁿ diet × duration interaction on backfat thickness at harvest; when fed the 75CS diet during the BKGⁿ period, SBKGⁿ steers accumulated more backfat than LBKGⁿ steers (Fig. 5).

DISCUSSION

The trend toward increased warming of the Canadian prairies combined with trends in

breeding corn hybrids that require shorter time to reach maturity has resulted in increased acreages of CS in western Canada (Gabruch and Gietz, 2014). Corn silage can be a useful alternative to small grain silage for beef cattle because of its potential for much greater (32%) yield and high digestible energy content (Baron et al., 2014a, 2014b). However, corn grown in western Canada does not consistently achieve its yield potential or DM content due to the limited growing season (Baron et al., 2014a). Our objective was to evaluate the effects of replacing BS with or without replacing a proportion of barley grain with increasing amounts of early-maturing CS (60, 75, and 90% of diet DM) on BKGⁿ and FIN cattle performance. We anticipated that CS would contain greater starch content than BS, thus enabling its dietary inclusion level to be increased up to 90% of diet DM without compromising animal performance. The starch content of CS used during BKGⁿ in the current study was 28.2% of DM. Baron et al. (2014a) reported that

Table 7. Production performance of finishing cattle fed backgrounding diets containing either barley silage (60%; DM basis) or increasing amounts of corn silage (60, 75, and 90%; DM basis) for a short or long duration

Item	Silage ^a				SEM	Duration of BKGN ^b		SEM	P-value ^c		
	CON	60CS	75CS	90CS		Short	Long		S	D	S × D
<i>n</i> , animals (pen)	40 (4)	40 (4)	40 (4)	40 (4)	–	80 (8)	80 (8)	–	–	–	–
Shrunk BW ^d , kg											
Initial (day 1 of FIN ^e)	451	452	460	449	4.7	425 ^x	481 ^y	3.3	0.426	<0.001	0.434
Final (end of FIN)	698	693	699	687	9.6	696	693	6.8	0.796	0.829	0.984
Duration of FIN, d	139	132	127	127	4	146 ^x	116 ^y	3	0.121	<0.001	0.024
DML, kg/d	10.9	11.2	11.5	11.5	0.26	11.0 ^x	11.6 ^y	0.19	0.354	0.045	0.301
ADG, kg/d	1.84	1.91	2.00	1.96	0.071	1.94	1.92	0.050	0.476	0.835	0.183
G:F	0.170	0.171	0.174	0.171	0.0063	0.177	0.166	0.0045	0.956	0.125	0.400
NE _g ^f , Mcal/kg of diet DM	1.35	1.34	1.36	1.32	0.045	1.36	1.32	0.031	0.909	0.452	0.667

^aCON = 60% barley silage; 60CS = 60% corn silage; 75CS = 75% corn silage; 90CS = 90% corn silage.

^bBKGN = backgrounding.

^cS = backgrounding diet; D = duration of backgrounding; S × D = backgrounding diet × duration of the backgrounding.

^dShrunk BW calculated as 96% of liveweight (National Research Council, 2000).

^eFIN = finishing.

^fCalculated based on performance (Zinn and Shen, 1998; Zinn et al., 2002).

^{x,y}Means for duration of backgrounding effect with different superscripts differ ($P < 0.05$).

starch content of CS from short-season hybrids can reach 30% (DM basis) in agreement with our study. The BS used in our study contained 24.2% starch (DM basis), a level much greater than we expected. Starch content of BS has been reported to range from 12.3% to 22.2% (DM basis) in other studies (Beauchemin and McGinn, 2005; Baron et al., 2014a; Benchaar et al., 2014). Numerous factors including the variety used (Nair et al., 2016) and the stage of maturity at harvest (Mowat and Slumskie, 1971) can account for the wide range

in the reported starch content for BS. Given the small difference in starch content between CS and BS (28.2 vs. average of 23.9% of diet DM) in our study, the starch content of the 60CS and CON diets also were comparable (34.6 vs. 34.9% of diet DM). However, the starch content of the 75CS and 90CS diets were 3.2 and 7.2% lower than the CON diet, respectively. This was due to the substitution of DM from CS for 50 or 100% of the DM from barley grain (average of 57.5% starch; DM basis) in those diets.

Figure 2. Effects of backgrounding (BKGN) diet and length of the BKGN period on the number of days to reach the finishing (FIN) end point shrunk BW. Backgrounding diets consisted of 60% barley silage (control; CON), or 60% corn silage (60CS), 75% corn silage (75CS), or 90% corn silage (90CS) on a DM basis. The BKGN period ended when the average pen weight was either 380 or 430 ± 15 kg for steers backgrounded for a short (SBKGN) or extended period (LBKGN), respectively. Pooled SEM = 5.14. Diet, $P = 0.121$; duration of backgrounding, $P < 0.001$; diet × duration of backgrounding, $P = 0.024$.

Figure 3. Dry matter (A) and NDF (B) intake (average of each 3-wk period) across diets for steers fed backgrounding (BKGN) diets consisting of 60% barley silage (control; CON), or 60% corn silage (60CS), 75% corn silage (75CS), or 90% corn silage (90CS) on a DM basis, and transitioned (periods 4 to 7) to a common finishing diet consisting of 9% corn silage, 86% dry-rolled barley grain, and 5% supplement on a DM basis. The BKGN period ended when the average pen weight was either 380 or 430 ± 15 kg for steers backgrounded for a short (SBKGN) or extended period (LBKGN), respectively. Error bars represent the standard deviation.

Inclusion level of CS in the BKGN diets decreased DMI compared with BS. Addah et al. (2011) also reported that DMI was lower for steers fed diets containing 60% CS (DM basis) compared to 60% BS. One of the key factors that regulates DMI is dietary NDF; typically, DMI decreases as dietary NDF content increases due to fill effects (Allen, 2000). Because CS contained a greater NDF content than BS or barley grain, replacing BS or barley grain with CS in the diet increased dietary NDF content by up to 10.8 percentage units in our study. Furthermore, the increase in NDF content was accompanied by up to a 50% increase in indigestible NDF content of the TMR with increasing proportions of CS. Differences in NDF content and its indigestibility probably account for the observed decrease in DMI by influencing digesta retention time (Allen, 2000).

The particle size distribution of BKGN diets also changed as the inclusion level of CS increased; the proportion of particles > 8 mm increased while the proportion of particles < 8 mm decreased. These changes were a result of the differences in the particle distribution of CS compared to BS and barley grain. A finer chop length adjustment during

CS harvest could remove this difference. Although orts comprised only 3.00, 3.17, 1.83, and 1.78% of TMR offered for the CON, 60CS, 75CS, and 75CS diets, respectively, the proportion of particles > 19 mm increased while those < 1.18 mm in orts actually decreased as the amount of CS in the diet increased. In addition, the decrease in starch content and concomitant increase in NDF content of orts with increasing inclusion level of CS suggests that selective consumption of TMR or sorting increased as dietary CS increased. Therefore, it is probable that cattle fed the BKGN diets containing CS spent a greater proportion of their eating time sorting for the smaller particles and the more rapidly or extensively fermentable carbohydrates in the TMR relative to the long and fibrous particles during meals. An increase in the amount of time cattle spend sorting for short particles and against long particles can result in a decrease in DMI due to a reduced feed consumption rate and increased competition at the feed bunk (Miller-Cushon and DeVries, 2016).

Increasing the dietary inclusion level of CS in our study also resulted in a decrease in dietary starch content by up to 7.2% (DM basis). This

Figure 4. Dry matter (A) and NDF (B) intake (average of each 3-wk period) across backgrounding (BKGN) duration for steers fed BKGN diets consisting of 60% barley silage (control; CON), or 60% corn silage (60CS), 75% corn silage (75CS), or 90% corn silage (90CS) on a DM basis, and transitioned (periods 4 to 7) to a common finishing diet consisting of 9% corn silage, 86% dry-rolled barley grain, and 5% supplement on a DM basis. The BKGN period ended when the average pen weight was either 380 or 430 kg for steers backgrounded for a short (SBKGN) or extended period (LBKGN), respectively. Error bars represent the standard deviation.

Table 8. Carcass quality traits of finishing cattle fed backgrounding diets containing either barley silage (60%; DM basis) or increasing amounts of corn silage (60, 75, and 90%; DM basis) for a short or long duration

Item	Silage ^a					Duration of BKGN ^b			<i>P</i> -value ^c		
	CON	60CS	75CS	90CS	SEM	Short	Long	SEM	S	D	S × D
<i>n</i> , animals (pen)	32 (4)	32 (4)	32 (4)	32 (4)	—	64 (8)	64 (8)	—	—	—	—
Carcass traits											
HCW, kg	431	426	433	422	8.4	428	428	5.9	0.767	0.986	0.950
Dressing percentage, %	59.3	58.8	59.1	58.9	0.31	59.0	59.1	0.22	0.671	0.755	0.871
Rib eye area, cm ²	98.0	98.7	94.0	96.0	2.30	96.6	96.8	1.63	0.503	0.932	0.820
Backfat, mm	14.2	14.7	14.6	13.0	0.57	14.7	13.6	0.40	0.219	0.089	0.009
Meat yield, %	54.9	54.5	53.6	55.7	0.77	54.2	55.1	0.54	0.344	0.266	0.114
Quality grade, %											
AAA ^d , %	80.6	77.8	90.9	85.7	—	80.0	87.1	—	0.396	0.267	0.400
Liver score, %											
Abscessed ^e	44.0	52.8	45.5	40.0	—	48.6	42.9	—	0.764	0.483	0.940
Severely abscessed ^f	0.00	8.33	6.06	2.86	—	5.71	2.86	—	1.000	1.000	1.000

^aCON = 60% barley silage; 60CS = 60% corn silage; 75CS = 75% corn silage; 90CS = 90% corn silage.

^bBKGN = backgrounding.

^cS = backgrounding diet; D = duration of backgrounding; S × D = backgrounding diet × duration of the backgrounding.

^dCanada grade AAA = equivalent to USDA choice.

^eThe percentage of liver with at least 1 abscess.

^fThe percentage of liver with at least 4 small abscesses or at least 1 abscess with a diameter greater than 2.5 cm.

Figure 5. Effects of backgrounding (BKGN) diet and length of the BKGN period on backfat thickness at harvest. Backgrounding diets consisted of 60% barley silage (control; CON), or 60% corn silage (60CS), 75% corn silage (75CS), or 90% corn silage (90CS) on a DM basis. The BKGN period ended when the average pen weight was either 380 or 430 $\pm$ 15 kg for steers backgrounded for a short (SBKGN) or extended period (LBKGN), respectively. Pooled SEM = 0.807. Diet, $P = 0.219$; duration of backgrounding, $P = 0.089$; diet $\times$ duration of backgrounding, $P = 0.009$.

decrease in starch content, combined with reduced DMI with increasing levels of CS, reduced energy intake and the decrease in dietary energy supply explains the decrease in ADG and G:F as CS replaced more grain in the BKGN diet. In addition, the decrease in NDF digestibility when feeding CS also could reduce fermentable energy supply thus contributing to lower growth performance during BKGN. However, dietary NE_g content was not different across diets. Similarly, [Addah et al. \(2011\)](#) observed a decrease in ADG and G:F in steers fed 60% CS compared to 60% BS during BKGN that was linked to a decrease of DMI. However, feeding CS to steer calves (average initial BW of 223 kg) increased ADG and G:F in an earlier comparative study ([Mowat and Slumskie, 1971](#)). This was attributed to a greater digestible energy content for CS than for BS. Although we did not measure digestible DM or energy content in our study, the observed NE_g content of the various diets remained similar. The combination of similar NE_g content of diets and reduced DMI with increasing CS level could account for the reduced ADG with high proportions of CS compared with BS in our study that was not observed in other studies ([Mowat and Slumskie, 1971](#); [Burgess et al., 1973](#)).

Beef cattle producers can alter the duration of the BKGN phase substantially depending on numerous factors including economics, BW, the quality of the calves and their suitability for FIN, availability of cost-effective forages, and the prevailing and forecasted cattle market trends ([Peel, 2003](#)). Therefore, the second goal of our study was to evaluate the carryover effect of extending the BKGN phase on growth performance for steers fed diets containing an increasing amount of CS. Because CS contains higher starch content than

BS, we anticipated that feeding more early-maturing CS in place of BS for a longer BKGN duration should not compromise steer growth performance for the entire feeding period.

As expected, setting a higher end point BW (mean BW $\pm$ SD; 430 vs. 380 $\pm$ 15) extended the BKGN phase by 34 d for the LBKGN compared to SBKGN steers. Because the LBKGN steers were heavier at the end of BKGN, they also consumed a greater amount of feed per day compared to SBKGN steers; this also can explain the greater ADG for LBKGN than SBKGN steers. However, despite the decrease in dietary starch content and DMI as the CS inclusion level increased in our study, no diet $\times$ duration interaction for most growth parameters measured during the BKGN phase were significant.

Given its potential impact on subsequent production performance and economic returns, the feeding program used during BKGN must not compromise FIN performance or increase the cost of gain. With the exception of duration of FIN, feeding a higher amount of CS to either LBKGN or SBKGN steers had no effect on DMI, ADG, and G:F during the FIN period. One key factor that determines whether a BKGN phase feeding program influences FIN performance and carcass characteristics is the BW of cattle at the beginning of the FIN phase ([Reuter and Beck, 2013](#)). Typically, yearling-fed cattle, being heavier at the beginning of FIN, tend to have greater DMI and ADG, and lower G:F and days on feed, than calf-fed cattle. In our study, BW at the end of the BKGN period (average of 425 kg) and at the beginning of the FIN period (average of 472 kg) was quite similar across diets. Therefore, this may explain the lack of a BKGN diet effect on DMI, ADG, and G:F during the FIN period.

As expected, the LBKGN steers, being 56 kg heavier at the beginning of FIN, reached the FIN end point BW of 700 kg 30 d earlier than the SBKGN steers. However, this did not result in significant differences in DMI, ADG, and G:F during the FIN phase. Others ([Sainz and Vernazza Paganini, 2004](#); [Winterholler et al., 2008](#)) have reported that DMI and ADG were greater and G:F was lower during the FIN period for heavier than for lighter steers at the beginning of FIN. However, the differences in BW between the yearling- and calf-fed cattle in those trials ranged from 130 to 295 kg, a much greater difference than the 33 kg difference in our study. Therefore, it is probable that the difference in BW between LBKGN and SBKGN steers at the beginning of FIN in our study was not sufficiently substantial to affect FIN performance.

Regardless of the duration of the BKGN phase (SBKGN and LBKGN), all steers were fed to a constant FIN BW (700 ± 15 kg LW). Therefore, it was not surprising that HCW was similar across treatments. Similarly, dressing percentage, meat yield, rib eye area, and quality grade also did not differ across treatments. However, we observed a BKGN diet $\times$ duration interaction for backfat thickness; compared with steers fed the 75CS diet during the BKGN period, SBKGN steers had 0.6 cm more backfat than LBKGN steers. The SBKGN steers that were fed 75CS during BKGN also required 53 more days to reach the equal-BW end point for FIN than the LBKGN steers that were fed the 75CS during BKGN. Therefore, the longer duration to FIN for SBKGN as compared to LBKGN steers may account for the greater accumulation of back fat. This is in agreement with [Harris et al. \(1997\)](#) and [Klopfenstein et al. \(2000\)](#) who reported that a longer duration to FIN may have contributed the greater backfat for calf- than yearling-fed steers when both were finished to a constant liveweight end point.

The DM yield for CS, which is influenced by numerous factors including hybrid used and CHU received, is typically higher than for BS ([Baron et al., 2014a, 2014b](#)). In our study, we did not determine DM yield. However, we calculated the replacement value of CS for barley grain DM. Based on the G:F we observed during BKGN, and using a targeted BW gain of 120 kg, each kg of CS replaced 1.12 and 0.88 kg of dry-rolled barley at the 75 and 90% CS inclusion levels, respectively. Therefore, because of its higher DM yield and capacity to replace barley grain, it could be economical to replace CS for BS and much of the barley grain in the growing diets for steers.

Dietary inclusion of high amounts (up to 90% of diet DM) of early-maturing CS in place of BS and barley grain resulted in decreases in DMI and ADG, and a tendency for G:F to decrease during the BKGN period probably due to a decrease in dietary starch content and an increase in fiber content. As expected, LBKGN steers consumed more feed and gained more BW than SBKGN steers. However, carryover effects of the BKGN diet on FIN performance and carcass traits were minor. In conclusion, dietary inclusion of more CS in place of BS, while extending the BKGN period, had only marginal effects on FIN performance and carcass traits in our study. Thus, early-maturing CS is a viable forage source for beef producers, but future studies are needed to determine effects of chemical composition of CS due to hybrid and growing conditions on performance of feedlot cattle.

ACKNOWLEDGMENTS

The study was funded by Beef Cattle Research Council (Canada) and Agriculture and Agri-Food Canada. The authors thank Pioneer Hi-Bred Ltd, Chatham, ON, Canada for supplying corn seed and inoculant for the study. We also thank the staff of the Research Feedlot for animal care and lab technicians (K. Andrews, B. Farr, L. Holtshausen, and D. Vedres) for sample analyses.

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