CSIRO PUBLISHING

Animal Production Science
https://doi.org/10.1071/AN17585

Brown-midrib corn silage in finishing steer diet: effects on animal performance, *in vivo* digestibility and ruminal kinetics disappearance

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Abstract. Lower lignin content in brown-midrib corn silage (BMRCS) than in conventional corn silage results in greater digestibility and dry-matter intake. Despite this advantage, the use of BMRCS has not been widely evaluated in beef cattle. The aim of the present study was to determine the effects of BMRCS chopped at 22-mm as the main component (79% DM basis) for finishing steer diet on digestion, animal performance and ruminal kinetics disappearance. In a first trial, 56 Angus and crossbred steers (339 ± 18 kg initial bodyweight) were divided into 14 pens that were randomly assigned to one of the following two treatments: BMR total mixed ration (BMRT) or conventional total mixed ration. Data were analysed under a completely randomised design using pen as the experimental unit ($n = 7$). In a second trial, BMRCS and conventional corn silage were incubated (0, 3, 6, 12, 24, 36, 72 and 120 h) in the rumen of three ruminally cannulated cows. Data were analysed under a completely randomised block (cow) design. The inclusion of BMRCS in 79% corn silage diet for finishing steers improved total diet neutral detergent fibre and acid detergent fibre digestibility, but did not improve DM digestibility. While there was no significant improvement in animal performance, carcass yield was improved in BMRT. Future studies are needed to evaluate the improvement of carcass weight in steers fed BMRT.

Additional keywords: beef cattle, BMR, fibre digestibility, lignin.

Received 23 August 2017, accepted 30 December 2017, published online 6 April 2018

Introduction

The high content of low-digestibility neutral detergent fibre (NDF) of whole corn silages may limit dry-matter intake (DMI) in dairy cows and beef steers by a physical fill effect of the rumen (Allen 1996; Oba and Allen 1999*a*). This physical limitation can be overcome by increasing ruminal passage rate by reducing corn-silage particle size (Jaster and Murphy 1983; Martz and Belyea 1986). However, this would reduce feed efficiency. In contrast, if physical fill is reduced by increasing the rate of ruminal NDF disappearance (Oba and Allen 1999*b*, 2000), more energy would be available (Keith *et al*. 1981; Gehman *et al*. 2008). Consequently, both DMI (Dado and Allen 1995; Jung *et al*. 2012) and animal performance might be increased (Oba and Allen 1999*a*, 2000; Holt *et al*. 2013), without negatively affecting feed efficiency. Therefore, different research groups have focussed their research efforts in selecting corn hybrids that combine a high forage yield with high starch and fibre digestibility (Eastridge 1999; Mahanna 2005; Jung *et al*. 2012).

Brown-midrib corn silages (BMRCS) have a lower total lignin content and an altered structure of the lignin (Cherney *et al*. 1991; Jung and Allen 1995; Hatfield *et al*. 1999; Marita *et al*. 2003). Lower lignin content has been associated with greater cell-wall digestibility (Cherney *et al*. 1991; Jung and Allen 1995).

Higher fibre digestibility has been reported for BMRCS than for conventional corn silages (CCS; Eastridge 1999; Oba and Allen 1999*b*; Gencoglu *et al*. 2008). In addition, several studies have reported higher *in vitro* (Taylor and Allen 2005; Stone *et al*. 2012; Holt *et al*. 2013; Genero *et al*. 2016) and *in vivo* digestibility of total dietary NDF (NDFD) when a BMRCS replaces CCS in the diet (Oba and Allen 1999*b*; Tjardes *et al.* 2000; Barlow *et al.* 2012; Schwarm *et al.* 2015). Whereas others (Oba and Allen 1999*b*; Greenfield *et al.* 2001; Barlow *et al.* 2012; Schwarm *et al.* 2015; Genero *et al.* 2016) have observed that the higher NDFD in BMRCS than in CCS does not result in a higher total dietary DM digestibility (DMD). In most of these studies, corn silage represented less than 60% of the diet.

Few studies have evaluated beef cattle performance when feeding BMRCS and inconsistent effects have been observed (Keith *et al.* 1981; McEwen *et al.* 1996; Tjardes *et al.* 2000; Saunders *et al.* 2015). Keith *et al.* (1981) and Tjardes *et al.* (2000) observed that inclusion of a BMRCS, as compared with CCS, in 88% and 86% corn-silage diet increased the DMI of heifers and steers respectively, but only Keith *et al.* (1981) found increased average daily gain (ADG) and similar feed conversion (FC). McEwen *et al.* (1996) observed an improvement in ADG and FC when steers were fed a 92% corn-silage diet containing BMRCS, compared with diets containing CCS. Keith *et al.* (1981) also reported a higher ADG and a similar FC when feeding steers with an 88% BMRCS diet, compared with those fed CCS-based diet. When the percentage of corn silage was 49%, Saunders *et al.* (2015) found a similar DMI and a tendency for increased ADG and FC in rations containing BMRCS, compared with CCS.

Among the studies mentioned above (Keith *et al.* 1981; McEwen *et al.* 1996; Tjardes *et al.* 2000; Saunders *et al.* 2015), only Tjardes *et al.* (2000) reported the theoretical cut length, which was 9.5 mm. This, fine chop length may increase DMI (Schwab *et al.* 2002; Kononoff *et al.* 2003), with a consequent increased ruminal particulate passage rate (Andrae *et al.* 2001; Nasrollahi *et al.* 2015). Oba and Allen (1999*a*) and Tjardes *et al.* (2000) explained that the higher passage rate associated with increased DMI could have reduced ruminal retention time for BMRCS-based diet, which should have reduced total tract digestibility of DM, NDF and ADF. Therefore, it was hypothesised that in a 79% corn-silage diet, chopped to a theoretical length of 22 mm, the use of BMRCS would increase DMD, NDFD, and total DMI and, thus, would improve animal performance, as compared with the use of CCS.

Materials and methods

The study was conducted at the Balcarce Agricultural Experimental Station of the National Institute of Agricultural Technology (Balcarce, Buenos Aires, Argentina). Fifty-six Angus and crossbred (unknown pedigree and breed fractions; with varying percentages of Angus and Hereford) steers (339 ± 18 kg) were assigned to 1 of 14 pens (four steers/pen). The pens were assigned randomly to one of the following two dietary treatments (seven pens/treatment) defined by the corn silage used (Table 1) in the total mixed ration (TMR) formulation: BMRCS-based TMR (BMRT) or CCS-based TMR (CT).

Table 1. Chemical composition of brown-midrib corn silage (BMRCS), conventional corn silage (CCS), sunflower meal (SFM) and total mixed rations including brown-midrib (BMRT) and conventional (CT) corn silages

ADF, acid detergent fibre; ADL, acid detergent lignin; CP, crude protein; NDF, neutral detergent fibre; OM, organic matter; WSC, washer soluble carbohydrate; n.d., not determined

Parameter	BMRCS (*n* = 6)	CCS (*n* = 6)	SFM (*n* = 4)	BMRT	CT
Silage chemical composition					
DM (%)	29.33 ± 2.77	30.13 ± 1.76	92.50 ± 2.12		
OM (% DM)	93.87 ± 0.63	94.58 ± 0.95	93.00 ± 0.49		
CP (% DM)	7.12 ± 1.43	6.12 ± 0.62	34.60 ± 0.85		
Starch (% DM)	26.95 ± 4.60	27.50 ± 7.89	0.70 ± 0.50		
WSC (% DM)	13.78 ± 1.79	14.55 ± 1.31	n.d.		
NDF (% DM)	36.02 ± 5.11	39.90 ± 7.48	35.20 ± 3.68		
ADF (% DM)	19.20 ± 2.29	22.43 ± 4.26	23.60 ± 5.80		
ADL (%DM)	2.54 ± 0.43	2.75 ± 0.27	8.22 ± 0.27		
Ingredient composition (% in diet DM)					
Corn silage				79.4	79.2
Sunflower meal				19.0	19.0
Urea				0.0	0.2
Mineral supplement[A]				1.6	1.6
Chemical composition[B] (% in diet DM)					
DM				40.86	41.44
OM				92.23	92.60
CP				12.20	12.00
Starch				21.53	21.91
NDF				35.28	38.30
ADF				19.73	22.25
ADL				3.61	3.77

[A]Composition: calcium 15.7%; phosphorus 0.6%; magnesium 1.8%; sulfur 1.0%; sodium chloride 9.8%; selenium 7.0 mg/kg; zinc 1245 mg/kg; manganese 1254 mg/kg; copper 352 mg/kg; cobalt 3.6 mg/kg; iodine 12 mg/kg; iron 800 mg/kg; ionophore 1000 mg/kg.

[B]Estimated from composition of individual ingredients.

The steers were adapted to the experiment setup and to the diets for 3 weeks. During the first 2 weeks, all the steers were fed CT and, during the last week, the assigned diets. The TMRs were formulated to contain 12% crude protein (CP, DM basis; Table 1).

The steers were fed once a day (0900 hours) an *ad libitum* amount of the TMR with at least 10% of daily feed refusal. To estimate the daily amount of feed to be offered and to determine the total DMI, the amount of feed offered and refused was recorded daily. Feedstuffs and refusals were dried at 100°C for 24 h for DM determination.

The steers were weighed at the beginning and at the end of the evaluation period (73 days), with weights being obtained on two consecutive days. Individual ADG was calculated by dividing the difference between the final bodyweight (BW) and initial BW by the number of days of the experimental period (73 days). FC (kg DMI/kg ADG) was estimated from DMI and ADG data. Also, BW was recorded at Days 17, 29, 42, and 56, and was used to determine the ADG and to adjust the amount of TMR.

After the evaluation period, the steers were kept on their respective treatments for another 12 days. On Day 85, they were weighed after 12 h of feed withdrawal and shipped (200 km) to a commercial slaughterhouse where they were harvested the following morning. At slaughter, hot carcass weight (HCW) was recorded. After 24 h of chilling, the 12–13th-rib sections from the left side of each carcass were removed. *Longissimus* muscle rib eye area and dorsal subcutaneous fat thickness were determined on the caudal side of the rib sections removed. Carcass yield was estimated from HCW and pre-shipment BW data. Dietary net energy for maintenance and gain was calculated using performance data (ADG, BW and DMI) as described Zinn and Plascencia (1996).

The silages used in each TMR were prepared from two corn hybrids, namely, a BMR hybrid (BMR126HX, Dow AgroSciences, Colón, Argentina) and a conventional hybrid (experimental hybrid EM0429HX, Dow AgroSciences). The genetic affinity between hybrids was estimated by single-nucleotide polymorphism markers to be 98.6.

The hybrids were seeded in adjoining 4-ha field plots in spring 2010 (26 and 28 October) in 52-cm rows to achieve a population of 80 000 seeds per hectare. Both hybrids were harvested 28 February at 1/4 milkline stage of kernel maturity, by using a commercial harvester (Model FX 375, New Holland, New Holland, PA, USA) and setting the theoretical cut length of chop at 22 mm. The hybrids were placed in separate silo bags (Silobolsa® Plastar San Luis SA, San Luis, Argentina). At harvest, samples of the chopped corn hybrids were collected every other truck load. The hybrid samples were composited and conserved in experimental mini-silo bags (20 × 40-cm polyvinyl bags vacuum packaged).

In vivo *TMR digestibility*

In vivo TMR digestibility was estimated using indigestible NDF (iNDF) as an internal marker of the digesta flow (Lippke *et al.* 1986). Starting on Days 59 and 66 of the experimental period, faecal samples were collected twice daily (0600 hours and 1500 hours) for five consecutive days from all the steers of two randomly selected pens of each dietary treatment. Therefore, a total of four pens (16 steers) per dietary treatment was sampled.

The pooled feedstuffs and the pooled faecal samples were dried at 60°C in a forced-air oven for 48 h and 96 h respectively, to determine the DM. Then they were ground through a Wiley mill equipped with a 1-mm screen before determining NDF, ADF and acid detergent lignin (ADL) concentrations as described in *Sample analysis*. The samples collected during the faecal-collection period were also analysed for iNDF. Briefly, the samples were incubated *in situ* for 12 days (Huhtanen *et al.* 1994) in the rumen of a cannulated cow with *ad libitum* access to tall fescue hay. Samples were incubated using six filter bags (F-57, Ankom Technology, Macedon, NY, USA) with 0.5 g of DM of each sample, and six empty filter bags were used as blanks. After incubation, the filter bags were washed with tap water and dried at 60°C for 48 h, and the NDF content was determined on the residue. Total dietary-DM digestibility was calculated as DMD (%) = $100 \times [1 - (iNDF_{TMR}/iNDF_{faeces})]$. NDFD, ADFD and total dietary-ADL digestibility (ADLD) were calculated as follows: NDFD, ADFD or ADLD (%) = $100 \times [1 - (iNDF_{TMR}/iNDF_{faeces}) \times (X_{faeces}/X_{TMR})]$, where X = NDF, ADF or LDA content.

Ruminal degradation of silage

The corn-silage samples ensiled in the mini-silo bags were used to determine the effects of corn hybrid on ruminal kinetics parameters. The samples were dried (60°C for 48 h in a forced-air oven) and ground with a Wiley mill equipped with a 6-mm screen (Sapienza 2002).

The corn-silage samples were incubated *in situ* for 0, 3, 6, 12, 24, 36, 72 and 120 h in the rumen of three cannulated cows with *ad libitum* access to tall fescue hay (89.0% DM; 90.4% organic matter; 63.3% *in vitro* DM digestibility; 11.6% CP; 63.3% NDF; 35.1% ADF). For each sampling time, two Dacron bags (10 × 20 cm; 50-µm pore size; Ankom Technology) containing 5 g DM of CCS, two Dacron bags containing BMRCS and an empty bag (used as blank) were incubated in each cow. Prior to their incubation, the samples were soaked in tap water for 20 min. After their removal from the rumen, the bags were washed with tap water until rinse water remained clear and were then frozen at −20°C for subsequent analysis.

Sample analysis

The corn silages and the sunflower-meal samples were dried at 60°C in a forced-air oven for 48 h to determine DM. Then they were ground through a Wiley mill equipped with a 1-mm screen, before determination the chemical composition.

Organic matter was determined by ashing at 450°C for 5 h. CP content was measured by combustion method with a Leco FP-528 N analyser (Leco Corporation, Saint Joseph, MI, USA), as proposed Horneck and Miller (1998). NDF, ADF and ADL concentrations were sequentially determined by using an ANKOM$^{200/220}$ fibre analyser (Ankom Technology), according to the manufacturer's instructions. Starch concentration was determined as described by MacRae and Armstrong (1968) and the concentration of water-soluble carbohydrates according to Bailey (1958).

The Dacron bags containing the residue samples after *in situ* incubation were dried at 60°C for 48 h to determine DM and the residues were ground through a Cyclotec mill (Cyclotec TM1093, Tecator TM Technology, Sweden) equipped with a 1-mm screen for subsequent NDF, ADF and ADL analysis, as described above. DM, NDF and ADF ruminal kinetics parameters were estimated using NLIN procedure for segmented model of SAS/STAT (2002) according to Fadel (2004). As the model could not converge for the ADL residue, disappearance at each incubation period was evaluated as a repeated measure in a completely randomised design.

Statistical analyses

Performance (n = 7) and *in vivo* digestibility (n = 4) data were analysed as a completely randomised design using pen as the experimental unit. Initial BW (Day 0) was used as a covariate for analysis of DMI, ADG and FC data. While DM, NDF and ADF ruminal kinetics parameters were analysed as a completely randomised block design, where each cow was considered as a block ($n = 3$). Analyses were performed with the general linear modelling procedure of SAS/STAT (2002). The residues of ADL were analysed by using a general linear model for repeated measures with the Proc MIXED of SAS/STAT (2002). Residuals of ADL, incubation period and their interaction were included as fixed effects. A compound symmetry covariance structure was used to account for the correlation among the measurements made within the same cow. Treatment effects for all data were considered different at a significance level of $P < 0.05$.

Results and discussion

In contrast to what was expected, no differences were observed between dietary treatments in DMI, ADG and FC (Table 2) during the 73 days of the finishing period. Similar results were observed by Saunders *et al*. (2015) when feeding growing steers with 49% (DM basis) corn-silage diets. When feeding heifers from weaning to slaughter with 88% corn-silage diets, Keith *et al*. (1981) observed higher DMI (0.47 kg/day) and ADG (0.13 kg/day) with BMRT than with CT, whereas no differences in DMI and ADG were observed when the proportion of corn silage in the diet was reduced (59% and 27% DM basis) by adding corn grain (1% and 2% BW). No differences in FC between the BMR and the CCS were observed by Keith *et al*. (1981) when corn grain was included at the three different levels in the ration. The same researchers (Keith *et al*. 1981) reported improvement in ADG of steers fed an 88% corn-silage diet containing BMRCS, compared with diet containing CCS. Nevertheless, when corn grain was added to the diet at a level of 2% of BW, ADGs of cattle fed both diets did not differ (Keith *et al*. 1981).

According to Keith *et al*. (1981), the increased proportion of readily fermentable carbohydrates when corn grain was added to the diet would have reduced fibre digestion, leading to reducing or masking the differences in fibre digestion between BMRCS and CCS, and that may have caused the higher DMI in BMRT when the 88% corn-silage diet was fed. Saunders *et al*. (2015) suggested that the higher ruminal production of propionate with BMRT than with CT may have limited DMI, offsetting the potential positive effect of a higher NDFD of the BMRCS on DMI. In agreement with Saunders *et al*. (2015), Schwarm *et al*. (2015) observed higher ruminal proportions of propionate and higher NDFD with BMRT than with CT (92% corn-silage diets), but similar DMI. Schwarm *et al*. (2015) attributed the lack of DMI differences between dietary treatments in their study to the fact that the higher (7.5%) NDFD in BMRT did not lead to higher DMD and rumen clearance time. In the present study, as also reported by Schwarm *et al*. (2015), a 6.1% increase in NDFD and 4.2% in ADF digestibility (ADFD) observed with BMRT, compared with CT ($P < 0.05$; Table 3), did not lead to a higher DMD in BMRT ($P = 0.26$). Despite NDFD content being two to eight percentage units higher in BMRT, similar DMDs between BMRT and CT have been reported previously (Oba and Allen 1999*b*; Greenfield *et al*. 2001; Ebling and Kung 2004; Barlow *et al*. 2012; Genero *et al*. 2016).

Despite higher NDFD and ADFD in BMRT, estimated NE_m and NE_g of the diets were similar (Table 2). This result supports the fact that HCW, rib eye area and subcutaneous fat

Table 2. Effect of experimental diets on animal performance, dietary net-energy content, and carcass traits

ADG, average daily gain; BW, bodyweight; CT, conventional corn silage-based total mixed ration; BMRT, brown-midrib corn silage-based total mixed ration; DMI, dry-matter intake; FC, feed conversion; HCW, hot carcass weight; REA, rib eye area; SCFT, subcutaneous fat thickness

Parameter	BMRT	CT	s.e.	*P*-value
		BW (kg)		
Day 0	343	336	9.57	0.17
Day 73	452	443	15.34	0.29
		ADG (kg)		
Days 0–17	1.32	1.38	0.11	0.70
Days 17–29	1.74	1.68	0.11	0.69
Days 29–42	1.51	1.88	0.11	0.02
Days 42–56	1.21	1.26	0.11	0.73
Days 56–73	1.72	1.37	0.11	0.03
Days 0–73	1.47	1.49	0.04	0.72
		DMI (kg/steer.day)		
	11.18	11.57	0.23	0.28
% of BW	2.86	2.91	0.13	0.65
FC (kg DMI/kg ADG)	7.64	7.82	0.25	0.63
		Net energy[A] *(Mcal/kg DM)*		
Maintenance	1.67	1.63	0.08	0.38
Gain	1.05	1.02	0.07	0.38
Pre-shipment BW (kg)	471	468	17.70	0.65
HCW (kg)	259	251	9.16	0.11
Carcass yield[B] (%)	55.10	53.60	0.93	0.01
REA (cm^2)	64.65	64.32	2.75	0.83
SCFT (mm)	7.05	6.62	1.07	0.46

[A]Estimated according to Zinn and Plascencia (1996).
[B]Estimated from HCW and pre-shipment BW.

Table 3. Effect of experimental diets on *in vivo* apparent digestibility

ADF, acid detergent fibre; ADL, acid detergent lignin; BMRT, brown-midrib corn silage-based total mixed ration; CT, conventional corn silage-based total mixed ration; NDF, neutral detergent fibre

Digestibility (%)	BMRT	CT	s.e.	*P*-value
DM	68.07	69.01	1.06	0.26
NDF	54.04	50.74	1.83	0.04
ADF	54.37	52.09	1.23	0.04
ADL	4.92	5.42	2.82	0.81

thickness were not significantly (P = 0.11) different between diets (Table 2). Nevertheless, carcass yield was 3.3 units % higher in BMRT than in CT. This may be the result of a lower ruminal content in BMRT due to higher passage rate associated with the observed higher NDFD and ADFD in BMRT (Dado and Allen 1995; Oba and Allen 2000). Gorniak *et al*. (2014) suggested that BMR corn particles are more susceptible to microbial fermentation and breakdown, and may have a greater probability of leaving the rumen. In agreement with this, Tjardes *et al*. (2000) reported a longer ruminal NDF turnover time and a higher ruminal NDF for *ad libitum* CT than for *ad libitum* BMRT. Oba and Allen (2000) and Greenfield *et al*. (2001) observed, in dairy cows, a faster ruminal turnover rate of NDF in BMRT than in CT.

In the current study, no statistical differences on pre-shipment BW and HCW, but higher carcass yield, in BMRT would suggest a lower ruminal content in BMRT than in CT. If there were a physical constraint to DMI in CT, the lower ruminal fill in BMRT would have allowed a greater DMI. However, as NE_m and NE_g did not differ between the treatments and the ADGs were relatively high, it would indicate that DMI was not limited by rumen distention, but probably by hepatic oxidation of propionate, as suggested by Saunders *et al*. (2015). The liver is likely to be involved in regulation of feed intake by propionate (Allen *et al*. 2009), which is rapidly metabolised in the liver (Reynolds 1995) and can stimulate hepatic oxidation, which may downregulate feed intake (Allen *et al*. 2009).

As observed by Sommerfeldt *et al*. (1979) and Genero *et al*. (2016), the higher NDFD and ADFD in the BMRT were not associated with a lower ADL concentration. Different studies have reported that higher NDFD in BMR were related with a lower lignin concentration (Oba and Allen 1999*b*; Tine *et al*. 2001; Kung *et al*. 2008; Holt *et al*. 2010), but others (Cherney *et al*. 1991; Jung and Allen 1995; Hatfield *et al*. 1999) have reported that differences in NDFD may also be associated with a different lignin structure. The syringyl–guaiacyl ratio showed a better relationship with cell-wall degradability than did the ADL concentration (He *et al*. 2018). Brown-midrib mutant contains a lower syringyl–guaiacyl ratio (Kuc *et al*. 1968; Barrière *et al*. 1994) than do conventional hybrids. With the maturation of plant cell wall, the syringyl–guaiacyl ratio increases and the digestibility of mature cell walls decreases (Grabber *et al*. 2004; He *et al*. 2018). Thus, it is assumed that lignin composition affects digestibility (Jung and Allen 1995). Also, digestibility of corn silage is directly affected by the degree of cross-linking of phenolics within the cell-wall carbohydrates (Raffrenato *et al*. 2017). In the current experiment, if lignin structure was different between BMRCS and CCS, it did not affect corn-silage ADL ruminal disappearance (data not shown) or ADLD (P = 0.81).

The observed higher NDFD in the BMRT was related to a greater NDF washout of corn-silage incubation in the rumen (10.31% of DM; P < 0.01; Table 4). This washout may have occurred during the 20-min hydration in tap water as a result of particle loss through the Dacron bags. Qiu *et al*. (2003) also observed a higher NDF washout for BMRCS than for CCS and suggested that some portion of the NDF in BMR was more fragile, and thus easily broke into small particles and washed out of the *in situ* bags.

Table 4. Dry matter, neutral detergent fibre (NDF) and acid detergent fibre (ADF) ruminal kinetics parameters of brown-midrib corn silage (BMRCS) and conventional corn silage (CCS)

Parameter	BMRCS	CCS	s.e.	*P*-value
DM				
Soluble fraction[A] (%)	22.79	25.22	0.53	0.08
Potentially degradable fraction[A] (%)	68.36	56.48	2.75	0.09
Indegradable fraction[A] (%)	8.84	18.3	3.25	0.17
Disappearance rate (%/h)	3.37	2.96	0.45	0.59
Lag time (h)	0.00	0.00	–	–
NDF				
Washout[A] (%)	10.31	2.75	0.51	<0.01
Potentially degradable fraction[A] (%)	35.78	29.84	2.09	0.16
Indegradable fraction[A] (%)	4.72	11.18	2.08	0.16
Disappearance rate (%/h)	2.35	2.11	0.29	0.63
Lag time (h)	9.84	13.55	2.77	0.45
ADF				
Washout[A] (%)	4.62	4.26	0.50	0.66
Potentially degradable fraction[A] (%)	19.44	17.80	1.14	0.41
Indegradable fraction[A] (%)	3.65	5.41	1.08	0.37
Disappearance rate (%/h)	2.83	1.96	0.27	0.15
Lag time (h)	15.59	12.95	7.02	0.81

[A]% total dry matter.

Consistent with the findings of Qiu *et al*. (2003), in the current experiment, this potentially greater NDF fragility in the BMR was not associated with a higher fractional disappearance rate of the potentially degradable NDF fraction (P = 0.63) or with a greater potentially degradable fraction of the NDF (P = 0.16). Similar NDF disappearance rates between BMRT and CT were also observed by Oba and Allen (2000). According to these authors, lower ruminal pH in BMRT than in CT may depress NDF digestion rates; however, this may have not been the case in the present study as corn silages were incubated under similar ruminal conditions. Others have reported that either BMRT (Bal *et al*. 2000; Greenfield *et al*. 2001) or BMRCS (Goto *et al*. 1993; Tovar-Gómez *et al*. 1997) had a higher ruminal NDF disappearance rates than did CCS or CT.

Conclusions

The inclusion of BMRCS in a diet with 79% corn silage for finishing steers improved total NDF and ADF digestibility but did not improve DM digestibility. While there was no significant improvement in animal performance, such as in DMI, FC and body gains, the carcass yield was improved in the BMRT. Further research is warranted to evaluate the possibility of obtaining carcasses of greater weight in steers fed diets with a high BMRCS inclusion.

Conflicts of interest

This research was partially funded by Dow AgroSciences (Colón, Buenos Aires, Argentina).

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