

Effects of cooked molasses blocks and fermentation extract or brown seaweed meal inclusion on intake, digestion, and microbial efficiency in steers fed low-quality hay¹

J. L. Leupp, J. S. Caton,² S. A. Soto-Navarro,³ and G. P. Lardy

Department of Animal and Ranges Sciences, North Dakota State University, Fargo 50105

ABSTRACT: Five ruminally, duodenally, and ileally cannulated steers (376 ± 8.1 kg of initial BW) were used in a 5×5 Latin square to evaluate effects of cooked molasses block supplementation and inclusion of fermentation extract (*Aspergillus oryzae*) or brown seaweed meal (*Ascophyllum nodosum*) on intake, site of digestion, and microbial efficiency. Diets consisted of switchgrass hay (6.0% CP; DM basis) offered ad libitum, free access to water, and one of three molasses blocks (0.341 kg of DM/d; one-half at 0600 and one-half at 1800). Treatments were no block (control), block with no additive (40.5% CP; POS), block plus fermentation extract bolused directly into the rumen via gelatin capsules (2.0 g/d; FS), fermentation extract included in the block (2.0 g/d; FB), and seaweed meal included in the block (10 g/d; SB). Steers were adapted to diets for 14 d followed by a 7-d collection period. Overall treatment effect on hay OM intake tended (8.1 vs. 7.6 ± 0.5 kg/d; $P = 0.14$) to increase with block supplementation. Total OM intake (8.4 vs. 7.6 ± 0.5 kg/d; $P = 0.01$) increased in steers consuming block compared with control. Ap-

parent and true ruminal OM digestibility increased ($P = 0.05$) with block consumption. Steers fed SB had greater ($P = 0.10$) true ruminal OM digestibility compared with steers fed POS (61.0 vs. $57.9 \pm 1.6\%$). True ruminal CP digestibility increased ($P = 0.01$) with block supplementation compared with control (37.5 vs. $23.6 \pm 3.7\%$). Addition of fermentation extract did not affect intake or digestion. Treatments did not alter ruminal pH, total VFA, or individual VFA proportions; however, ruminal ammonia increased ($P = 0.01$) with block supplementation. In situ disappearance rates of hay DM (3.14 ± 0.44 %/h), NDF (3.18 ± 0.47 %/h), and ADF (3.02 ± 0.57 %/h) were not altered by treatment. Seaweed block increased ($P = 0.01$) slowly degraded CP fraction compared with POS (39.5 vs. $34.0 \pm 2.07\%$). Similarly, SB increased ($P = 0.01$) the extent of CP degradability (74.2 vs. $68.9 \pm 1.81\%$). No treatment effects ($P = 0.24$) were observed for microbial efficiency. Block supplementation increased intake, and use of brown seaweed meal seemed to have beneficial effects on forage digestibility in low-quality forage diets.

Key Words: Brown Seaweed Meal, Cattle, Cooked Molasses Block, Digestion, Fermentation Extract, Low-Quality Hay

©2005 American Society of Animal Science. All rights reserved.

J. Anim. Sci. 2005. 83:2938–2945

Introduction

Use of cooked molasses blocks as forage supplements is gaining popularity among beef cattle producers. Reasons for this include convenience, decreased costs (labor and fuel), improved forage intake and digestion (Löest et al., 2001), and cattle movement onto underutilized

rangeland (Bailey and Welling, 1999). Data indicate that steers consuming cooked molasses blocks containing base ingredients of beet molasses, cane molasses, or concentrated separator by-product (Greenwood et al., 2000) and varying levels of urea and/or feed-grade biuret as CP sources (Löest et al., 2001) increased intake and digestion of low-quality prairie hay (< 6.0% CP; < 70.0% NDF). These findings were attributed to increased degradable intake protein (DIP).

Fermentation extracts are fed to improve ruminal fermentation and production efficiency in cattle. Research with these products, particularly *Aspergillus oryzae*, has yielded variable results. Firkins et al. (1990) found no effect on fiber digestion when supplementing fermentation extract and yeast culture and 5% fat to Holstein heifers offered a basal diet containing 9.9% CP composed of 50% orchard grass hay, 20% corn, 20%

¹This research was funded in part by Ridley Block Operations, Mankato, MN. Gratitude is expressed to Animal and Range Sciences personnel for assistance with data collection and laboratory analyses.

²Correspondence: 185 Hultz Hall (phone: 701-231-7653; fax: 701-231-7590; e-mail: joel.caton@ndsu.nodak.edu).

³Current address: Dep. Anim. Range Sci., New Mexico State Univ., Las Cruces 88003.

Received November 14, 2004.

Accepted August 12, 2005.

soybean hulls, 5% cornstarch grits, and 5% soybean meal on a DM basis. Gomez-Alarcon et al. (1990) reported increased DM and NDF digestibility when 3 g/d of fermentation extract was supplemented to cows offered a diet containing 61% concentrate and 39% forage. Humphry et al. (2002) reported a tendency for increased DMI by heifers fed 2 g of fermentation extract/d and offered ad libitum access to tall fescue. Little research has evaluated inclusion of these products in cooked molasses blocks. If inclusion of fermentation extracts into cooked molasses blocks results in improved low-quality forage use, producers would have an additional management tool for use with cattle consuming low-quality forages.

Dietary inclusion of brown seaweed meal (*Ascophyllum nodosum*; Allen et al., 2001; Fike et al., 2001) enhanced immunity and antioxidant properties in cattle. Currently, no data exist evaluating inclusion of brown seaweed meal into cooked molasses blocks. Therefore, objectives of this study were to investigate effects of cooked molasses blocks and inclusion of a fermentation extract or brown seaweed meal on intake, digestion, duodenal protein supply, and microbial efficiency in steers fed low-quality hay.

Materials and Methods

Animals and Diets

All animal care, handling, and surgical techniques followed protocols approved by the North Dakota State University Animal Care and Use Committee. Five ruminally, duodenally, and ileally cannulated Holstein steers (376 ± 8.1 kg of initial BW) were used in a 5×5 Latin square. Steers were weighed at the initiation of the trial and housed in a climate-controlled room in individual pens (3.0 m \times 3.7 m) during each 14-d adaptation period and stalled in individual metabolism crates (1.0 m \times 2.2 m) during each 7-d collection period. Metabolism crates were designed to allow separation of urine and feces. Total fecal collections were performed using stainless steel pans placed directly behind the crates. Steers were offered diets twice daily (0600 and 1800) and allowed ad libitum access to water. Switchgrass hay (*Panicum virgatum*; 6.0% CP, 74.7% NDF, and 43% ADF; DM basis) was offered at 10% above the previous day's intake. Hay was chopped through a 10.16-cm screen. Treatments consisted of 1) no block (control), 2) block without additive (40.5% CP, DM basis; **POS**), 3) block without additive plus fermentation extract (*Aspergillus oryzae*; BioZyme, Inc., St. Joseph, MO) bolused directly into rumen via gelatin capsules (2.0 g/d, DM basis; **FS**), 4) fermentation extract included in block (2.0 g/d, DM basis; **FB**), and 5) brown seaweed meal (*Ascophyllum nodosum*; Acadian Agritech, Nova Scotia, Canada) included in block (10 g/d, DM basis; **SB**). Steers fed blocks received 0.341 kg of block daily (DM basis; one-half at 0600 and one-half at 1800). Cooked molasses blocks were fed in small pieces to allow steers to con-

Table 1. Nutrient content of hay and molasses blocks offered to steers, % DM basis

Item	Hay	Block treatment ^a		
		POS	FB	SB
Ash	7.2	15.0	21.4	22.4
CP	5.9	40.5	31.1	36.9
NDF	74.7	ND ^b	ND	ND
ADF	42.9	ND	ND	ND

^aCON = no block, POS = 341 g (DM basis) of control block offered per steer daily, FB = 341 g of block containing fermentation extract offered per steer, and SB = 341 g of block containing seaweed meal offered per steer daily.

^bND = not determined.

sume them within 1 h. Cooked molasses blocks were formulated to contain 40% CP (DM basis) and to meet or exceed degradable intake protein requirement when fed 0.341 kg of DM/d. Cooked molasses blocks used in the study were a proprietary formula of Crystalyx brand supplements, formulated with beet molasses, and manufactured by Ridley Block Operations, Worthington, MN. Analyzed nutrient content of the diet is shown in Table 1.

Sample Collection

Experimental periods consisted of 14 d of adaptation followed by a 7-d collection period. Diet samples were collected weekly (approximately 200 g) and composited within period. Ort samples (10% of total) were taken daily, before the morning feeding (0530), throughout the 7-d collection period. Five days before and throughout collections, 8 g of chromic oxide were dosed ruminally twice daily at 0600 and 1800 via gelatin capsule (Torpac, Inc., Fairfield, NJ) for use as a digesta flow marker. Total fecal output was determined daily. Fecal subsamples (10% of output; wet-weight basis) were composited within steer and period. Subsamples were stored (-20°C) until mixed in a rotary mixer (Model H-600; Hobart Manufacturing Co., Troy, OH), where another subsample was taken and frozen (-20°C) until analyses. Duodenal and ileal samples (200 mL) were collected over 4 d in a manner that allowed for every other hour in a 24-h period to be sampled. Samples were taken on d 3 at 0800, 1400, and 2000; on d 4 at 0200, 1000, 1600, and 2200; on d 5 at 0400, 1200, 1800, and 2400; and on d 6 at 0600 of each collection period. Samples were composited by steer within period and stored (-20°C) until analyses.

In situ DM, CP, NDF, and ADF disappearance was determined using Dacron bags (10 cm \times 20 cm; 53 ± 10 μm pore size; Ankom, Fairport, NY) containing 5 g (as-fed basis) of hay. Dacron bags were weighed, and 5 g of hay sample were added to bags; weights were then recorded. Grass hay was ground in a Wiley mill (Arthur H. Thomas, Philadelphia, PA) to pass a 2-mm screen before in situ analyses. Bags were presoaked in water at 39°C and ruminally incubated in duplicate at 98, 72,

48, 36, 24, 14, 9, 5, 2, and 0 h. The 0-h bags were used as correction factors. Extent of digestion was generated by the Mertens and Loften (1980) equation using nonlinear procedures of SAS. After incubation, all bags were removed and rinsed with tap water to remove large particulate matter. Bags were then rinsed using a top-loading washing machine (General Electric, Louisville, KY) on the delicate cycle. Bags were agitated for 1 min, drained, and spun for 2 min. This cycle was repeated until rinse water was clear (a minimum of six cycles). Bags were dried in a forced-air oven (55°C; The Grieve Corp., Round Lake, IL) for 48 h and stored at room temperature until analyses. In situ disappearance of forage DM and NDF was calculated using the model of Mertens and Loften (1980). In situ forage CP disappearance was calculated using the nonlinear model of Ørskov and McDonald (1979) and was not corrected for bacterial contamination.

Fluid dilution rate was estimated using CoEDTA as a fluid flow marker. Two hundred milliliters of CoEDTA (1734 mg of Co; Uden et al., 1980) was dosed intraruminally 2 h before feeding on d 6 of each collection period. Ruminal fluid samples (200 mL) were collected with a suction strainer at 0, 2, 4, 6, 8, 10, and 12 h after feeding, and pH was determined immediately with a combination electrode (Model 2000 pH/temperature meter; VWR Scientific Products, West Chester, PA). Ruminal fluid samples were then frozen (-20°C) until ammonia and Co analyses. A subsample (3 mL) of the initial, nonacidified ruminal fluid sample was collected and added to 0.75 mL of metaphosphoric acid (concentration 25% w/r) and frozen (-20°C) until analyzed for VFA.

On d 21 of each period, before the morning feeding, ruminal evacuations were conducted to determine ruminal fill. Ruminal contents were removed, weighed, and subsampled. Subsamples were obtained by hand-mixing ruminal contents in 208-L tubs and taking samples from various locations. A grab sample (650 g, wet basis) was taken for analysis of DM, OM, ADF, and NDF. A second ruminal content sample (4 kg) was taken, and 2 L of formalin/saline solution (3.7% formaldehyde/0.9% NaCl) were added (Zinn and Owens, 1986) for isolation of bacterial cells, which were later analyzed for DM, ash, N, and purines. Samples were stored frozen (-20°C) until analyses.

Laboratory Analyses

Diet, Orts, and fecal samples were dried using a forced-air oven at 55°C (The Grieve Corp.) for 48 h. Dried samples were ground in a Wiley mill to pass a 2-mm screen. Duodenal and ileal samples were lyophilized (Virtis Genesis 25LL; The Virtis Company, Inc., Gardiner, NY) and ground with a Wiley mill to pass a 1-mm screen.

Diet, Orts, duodenal, ileal, and fecal samples were analyzed for DM, ash, and N (Method No. 930.15, 942.05, and 984.13, respectively; AOAC, 1990). Concen-

trations of NDF (Robertson and Van Soest, 1991, as modified by Ankom Technology) and ADF (Goering and Van Soest, 1970, as modified by Ankom Technology) were determined using an Ankom 200 Fiber Analyzer (Ankom Technology) without sodium sulfite, with amylase, and without ash correction as sequential. Chromic oxide concentrations were analyzed in duodenal and ileal samples by the spectrophotometric method (Fenton and Fenton, 1979). Recovery of chromic oxide in the feces averaged $106.8 \pm 2.5\%$ across treatments. In situ residue from duplicate bags were composited and analyzed for DM, N, NDF, and ADF were analyzed as described previously.

Ruminal fluid samples were thawed for 12 h at 4°C before analysis. Ruminal fluid samples were centrifuged at $20,000 \times g$ for 20 min, and the supernatant fraction was taken for analysis of ammonia (Broderick and Kang, 1980). Ruminal VFA concentrations (Goetsch and Galyean, 1983) were quantified by gas chromatography (5890A Series II GC; Hewlett Packard, Wilmington, DE) using a capillary column. Cobalt was analyzed by methods described by Uden et al. (1980) with an air-plus-acetylene flame using atomic absorption spectroscopy (Model: 3030B; Perkin Elmer, Inc., Wellesley, MA).

Ruminal content from total evacuations was analyzed for DM and ash (AOAC, 1990). A Waring blender (Model 37BL19 CB6; Waring Products, New Hartford, CT) was used to blend ruminal contents. Samples were blended on high speed for 1 min, and the mixture was strained through four layers of cheesecloth. Fluid was placed in 250-mL centrifuge bottles and centrifuged at $500 \times g$ for 20 min to remove feed particles and protozoa. The supernatant fraction was removed and recentrifuged at $500 \times g$ for 20 min. Bacteria were separated from the free supernatant fraction by centrifuging at $30,000 \times g$ for 20 min. Isolated bacterial cells and duodenal contents were analyzed for purines (Zinn and Owens, 1986) as a microbial marker.

Statistical Analyses

Data were analyzed as a 5×5 Latin square using the Mixed procedure of SAS (SAS Inst., Inc., Cary, NC). The model included diet and period as fixed effects and steer as the random effect. Data over time were analyzed as a repeated measures design using the Mixed procedure of SAS. The model included period, animal, diet, time, diet \times time, and animal \times period \times diet; the random variable was animal. After detection of a significant *F*-test ($P < 0.10$) for treatment, means were separated using the following contrasts: CON vs. blocks, POS vs. fermentation extract, POS vs. SB, and FS vs. FB. In situ rates of forage DM, NDF, and ADF disappearance were calculated using the equation of Mertens and Loften (1980). In situ forage N disappearance was calculated using the equation of Ørskov and McDonald (1979).

Table 2. Effect of cooked molasses block supplementation on OM intake and digestion in steers offered low-quality hay

Item	Block treatment ^a					SEM ^c	<i>P</i> -value ^d	Contrast ^b			
	CON	POS	FS	FB	SB			CON vs. B	POS vs. F	POS vs. SB	FS vs. FB
Intake, kg/d											
Hay	7.63	8.01	8.09	7.88	8.39	0.52	0.14	0.06	0.91	0.25	0.45
Total	7.63	8.28	8.36	8.14	8.66	0.52	0.03	0.01	0.90	0.25	0.44
Duodenal flow, kg/d											
Bacterial	0.45	0.47	0.49	0.48	0.49	0.03	0.67	0.17	0.74	0.61	0.78
Apparent feed	3.32	3.36	3.40	3.16	3.24	0.19	0.13	0.70	0.34	0.27	0.02
Total	3.76	3.83	3.89	3.64	3.73	0.20	0.14	0.83	0.42	0.36	0.02
Ileal flow, kg/d	3.43	3.48	3.65	3.34	3.36	0.28	0.06	0.76	0.84	0.29	0.02
Fecal output, kg/d	4.07	4.27	4.26	4.07	4.07	0.28	0.62	0.55	0.54	0.34	0.33
Digestibility, % of intake											
Apparent ruminal	50.2	51.7	51.3	53.3	55.1	1.7	0.06	0.05	0.67	0.06	0.21
True ruminal	56.3	57.9	57.5	59.4	61.0	1.6	0.09	0.05	0.72	0.10	0.24
Small intestine	4.29	4.54	2.82	4.32	4.06	1.41	0.87	0.80	0.54	0.80	0.42
Large intestine	-7.02	-9.56	-5.31	-7.78	-6.45	1.90	0.62	0.91	0.23	0.28	0.38
Total tract	46.2	46.9	48.2	48.4	51.5	1.3	0.07	0.07	0.34	0.02	0.92

^aCON = no block, POS = 341 g (DM basis) of control block offered per steer daily, FS = 341 g of control block offered plus 2 g of fermentation extract bolused directly into rumen via gelatin capsule per steer daily, FB = 341 g of block containing fermentation extract offered per steer, and SB = 341 g of block containing seaweed meal offered per steer daily.

^bCON vs. B = no block vs. all blocks, POS vs. F = control block vs. fermentation block and fermentation extract provided separately, POS vs. SB = control block vs. seaweed block, and FS vs. FB = fermentation extract provided separately vs. fermentation block.

^cn = 5 observations per treatment.

^dProbability value for the *F*-test of overall treatment.

Results and Discussion

Analyzed composition of switchgrass hay and cooked molasses blocks is presented in Table 1. The hay averaged 6.0% CP, 74.7% NDF, and 43.0% ADF (DM basis). All blocks were formulated to contain 40% CP (DM basis); however, POS averaged 40.5% CP, whereas FB and SB averaged 31.1 and 36.9% CP, respectively.

The overall *F*-test of treatment for hay OM intake tended ($P = 0.14$; Table 2) to support the specific contrast for control vs. block treatments, which indicated that hay intake was increased ($P = 0.06$) in steers consuming block treatments. Similarly, total OM intake was increased ($P = 0.01$) with block supplementation. Mathis et al. (2000) reported no differences in forage or total OM intake with supplemental DIP when cattle consumed bermudagrass hay; however, they observed a linear increase in forage and total OM intake with increasing levels of DIP that was supplied when cattle consumed sorghum hay. In contrast, Toppo et al. (1997) and Heldt et al. (1999) observed an increase in forage and total OM intake when cattle were supplemented with wide ranges of protein levels when consuming low-quality forages. Similar to hay OM intake, the overall *F*-test of treatment for NDF and ADF intake tended ($P = 0.14$) to increase with block supplementation (data not shown). Toppo et al. (1997) and Greenwood et al. (2000) attributed an increase in NDF intake to an increase in DIP provided through the cooked molasses blocks. Overall *F*-test of treatment for total and apparent feed OM flow at the duodenum tended ($P < 0.14$) to increase in FS compared with FB. Specific contrasts indicated that fermentation extract delivered via bolus resulted in increased ($P = 0.02$) total and apparent feed

OM flow compared with FB. Bacterial OM flow at the duodenum and fecal OM output did not differ across treatments. Apparent ruminal, true ruminal, and total tract OM digestibility increased ($P < 0.07$) with block supplementation compared with the control and with SB vs. POS ($P < 0.10$). Increased OM digestibility agrees with the results of Toppo et al. (1997) and Löest et al. (2001), who supplemented 50 and 60% CP cooked molasses blocks to cattle consuming either straw or low-quality prairie hay, respectively. Löest et al. (2001) reported that improvements in OM digestibility might have been due to an increase in NDF digestibility; however, Greenwood et al. (1998) reported no differences in OM digestibility in cattle fed low-quality prairie hay supplemented with cooked molasses blocks. Similar to total tract OM digestibility, total tract ADF (42.7, 44.3, 45.5, 44.7, 48.2 ± 1.4%) and NDF digestibilities (46.4, 47.6, 48.9, 48.2, 51.6 ± 1.2% for CON, POS, FS, FB, and SB, respectively) were greater ($P < 0.05$) for block-supplemented steers compared with control steers and were greater for SB-fed steers compared with POS-fed steers. Greenwood et al. (2000) and Löest et al. (2001) reported increased NDF digestibilities with cooked molasses block supplementation, indicating increased digestion rates were more than enough to compensate for increased passages rates. Toppo et al. (1997) observed no differences in ADF digestibilities in cattle consuming straw supplemented with cooked molasses blocks.

By design, total CP intake was greater ($P = 0.01$; Table 3) for supplemented steers than for control steers. Hay CP intake was unchanged ($P = 0.18$) by treatment. Similar to trends in OM flow, apparent feed and total CP flow at the duodenum increased ($P < 0.03$) in steers fed blocks compared with control-fed steers. Bacterial

Table 3. Effect of cooked molasses block supplementation on CP intake and digestion in steers offered low-quality hay

Item	Block treatment ^a					SEM ^c	<i>P</i> -value ^d	Contrast ^b			
	CON	POS	FS	FB	SB			CON vs. B	POS vs. F	POS vs. SB	FS vs. FB
Intake, g/d											
Hay	502	523	531	520	543	34	0.18	0.05	0.88	0.27	0.51
Total	502	661	668	628	670	34	0.01	0.01	0.38	0.64	0.03
Duodenal flow, g/d											
Bacterial	225	243	250	240	246	13	0.56	0.13	0.86	0.83	0.50
Apparent feed	370	417	394	412	398	18	0.10	0.03	0.38	0.34	0.32
Total	594	661	643	652	643	24	0.03	0.01	0.45	0.42	0.64
Ileal flow, g/d	326	364	344	344	315	29	0.13	0.26	0.22	0.03	0.99
Fecal output, g/d	313	348	333	334	327	23	0.12	0.05	0.24	0.17	0.95
Microbial efficiency ^e	8.70	8.87	8.91	8.45	7.72	0.68	0.24	0.63	0.71	0.08	0.40
Digestibility, % of intake											
Apparent ruminal	-24.0	-1.79	0.41	-4.00	3.23	4.72	0.01	0.01	1.00	0.42	0.45
True ruminal ^f	23.6	36.5	38.8	34.2	40.4	3.7	0.03	0.01	0.99	0.46	0.36
Small intestine	59.7	46.7	48.0	46.1	50.5	4.5	0.14	0.02	0.93	0.51	0.74
Large intestine	4.01	2.50	3.90	4.05	-0.36	3.27	0.60	0.60	0.65	0.48	0.97
Total tract	37.3	47.7	50.3	46.8	51.2	1.3	0.01	0.01	0.59	0.07	0.06

^aCON = no block, POS = 341 g (DM basis) of control block offered per steer daily, FS = 341 g of control block offered plus 2 g of fermentation extract bolused directly into rumen via gelatin capsule per steer daily, FB = 341 g of block containing fermentation extract offered per steer, and SB = 341 g of block containing seaweed meal offered per steer daily.

^bCON vs. B = no block vs. all block, POS vs. F = control block vs. fermentation block and fermentation extract provided separately, POS vs. SB = control block vs. seaweed block, and FS vs. FB = fermentation extract provided separately vs. fermentation block.

^c*n* = 5 observations per treatment.

^dProbability value for the *F*-test of overall treatment.

^eGrams of microbial N per kilogram of OM truly fermented. Truly fermented OM = OM intake minus apparent feed OM flow at the duodenum.

^f[(CP intake – apparent feed CP flow at the duodenum)/CP intake] × 100.

purine-to-bacterial CP ratio averaged 7.061 across treatments. Duodenal bacterial flow was similar among treatments; however, the overall *F*-test of treatment for ileal CP flow tended (*P* = 0.13) to be significant. Resulting specific contrasts indicated that ileal CP flow was increased (*P* = 0.03) with SB compared with POS. With respect to CP digestibility, apparent ruminal, true ruminal, and total tract were increased (*P* = 0.01) with block supplementation. Toppo et al. (1997) and Löest et al. (2001) reported increased CP digestibility in steers supplemented with cooked molasses blocks, which indicates that protein supplementation increases ruminal ammonia N supply and possibly ruminal microbial growth. Total tract CP digestibility also was increased (*P* ≤ 0.07) with SB compared with POS and was increased with FS compared with FB. Reasons for these responses are unclear and warrant further investigation. The overall *F*-test of treatment for small intestinal digestibility tended (*P* = 0.14) to support the specific contrast, which indicated a decrease (*P* = 0.02) with block supplementation compared with controls. Treatment had no effect on large intestinal CP digestibility. Microbial efficiency (g of microbial N/kg of OM truly fermented) did not differ among treatments, which is contrary to findings of Köster et al. (1996), who reported a linear increase with increasing levels of DIP supplementation in cattle fed forage-based diets.

Treatment did not affect pH, total VFA, or molar proportions of acetate, propionate, and butyrate (Table 4). Heldt et al. (1999) reported no differences in pH, but observed an increase in total VFA concentrations

and a decrease in acetate proportions with increasing levels of DIP. Others also have reported increases in total VFA concentrations with a decrease in acetate and an increase in propionate proportions with increasing levels of DIP fed to cattle offered low-quality forages (Köster et al., 1996; Mathis et al., 2000). Block supplementation increased (*P* = 0.01) ruminal ammonia concentration. The increase in ammonia concentration was likely due to supplemental ruminal available N (Heldt et al., 1999). These findings agree with those of others, who reported increases in ammonia concentrations with supplemental DIP provided through sodium caseinate (Heldt et al., 1999; Olson et al., 1999; Mathis et al., 2000).

In situ disappearance rate of hay DM, NDF, and ADF was not altered by treatment (Table 5). Freeman et al. (1992) reported that NDF disappearance from prairie hay decreased at 4 h and increased at 24 h of incubation with DIP supplementation to steers consuming low-quality forage. Seaweed block increased (*P* = 0.01) slowly degraded CP fraction and extent of CP degradability compared with POS. Fermentation block decreased (*P* = 0.01) the soluble CP fraction and increased (*P* = 0.01) the slowly degraded CP fraction compared with FS. Reasons for this response are unclear, but it may be related to effects of block manufacturing on activity of fermentation extract used in this study. Degradation rate of CP did not differ among treatments (*P* = 0.59). In a study conducted by Carey et al. (1993), steers were supplemented with 195 g of CP daily; supplements were based on barley, beet pulp, or corn.

Table 4. Effect of cooked molasses block supplementation on ruminal pH, ammonia, and VFA in steers offered low-quality hay

Item	Block treatment ^a					SEM ^c	<i>P</i> -value ^d	Contrast ^b			
	CON	POS	FS	FB	SB			CON vs. B	POS vs. F	POS vs. SB	FS vs. FB
pH	6.53	6.53	6.46	6.52	6.50	0.03	0.51	0.55	0.33	0.49	0.18
Ammonia, mM	1.58	2.90	2.61	2.58	3.26	0.32	0.02	0.01	0.46	0.43	0.94
VFA											
Total, mM	89.3	89.2	96.5	92.8	88.5	6.15	0.87	0.72	0.48	0.93	0.68
Acetate, mol/100 mol	73.1	76.2	74.0	70.2	72.9	2.40	0.52	0.93	0.18	0.35	0.27
Propionate, mol/100 mol	15.6	16.4	16.1	15.3	16.2	0.58	0.64	0.53	0.31	0.77	0.36
Butyrate, mol/100 mol	8.0	8.6	8.4	7.8	8.7	0.54	0.69	0.51	0.42	0.89	0.46
Acetate:propionate	4.72	4.64	4.68	4.61	4.54	0.14	0.92	0.52	0.99	0.63	0.74

^aCON = no block, POS = 341 g (DM basis) of control block offered per steer daily, FS = 341 g of control block offered plus 2 g of fermentation extract bolused directly into rumen via gelatin capsule per steer daily, FB = 341 g of block containing fermentation extract offered per steer, and SB = 341 g of block containing seaweed meal offered per steer daily.

^bCON vs. B = no block vs. all blocks, POS vs. F = control block vs. fermentation block and fermentation extract provided separately, POS vs. SB = control block vs. seaweed block, and FS vs. FB = fermentation extract provided separately vs. fermentation block.

^cn = 28 observations per treatment.

^dProbability value for the *F*-test of overall treatment.

Steers were allowed ad libitum access to brome hay (9.9% CP). Those researchers reported that steers fed supplemental barley or corn had greater slowly degraded forage CP fractions than non-supplemented controls; however, the rapidly degraded forage CP fractions were greater for non-supplemented controls than for those supplemented with barley or corn.

Total ruminal fill did not differ (Table 6) across treatments, which agrees with the findings of DelCurto et al. (1990a,b) and Sunvold et al. (1991). Ruminal DM fill (kg/d) was not affected by treatment, but when expressed as grams per kilogram of BW, block-supplemented steers had increased (*P* = 0.08) fill. Sunvold et al. (1991) observed an increase in DM fill when supplemental CP level was increased from 15 to 25%. Contrary to these findings, Heldt et al. (1999) reported ruminal DM fill decreased in supplemented steers compared

with non-supplemented steers, which they attributed to increased fluid and particulate passage rates and increased OM digestion. In the current study, steers supplemented with fermentation extract had increased (*P* = 0.02) ruminal DM fill when expressed as grams per kilogram of BW compared with POS. Reasons for this response are unclear.

In summary, supplementation of low-quality hay with cooked molasses blocks increased OM intake and digestion of OM, CP, NDF, and ADF. In addition cooked molasses blocks tended to increase hay intake. These observations indicate potential production and management benefits from using cooked molasses blocks. Cooked molasses blocks also increased ruminal ammonia concentrations compared with the non-supplemented controls. Inclusion of fermentation extract resulted in no improvement over control blocks. Inclusion

Table 5. Effect of cooked molasses block supplementation on rate of DM, NDF, and ADF ruminal disappearance and CP kinetic parameter estimates of forage in steers offered low-quality hay

Item	Block treatment ^a					SEM ^c	<i>P</i> -value ^d	Contrast ^b			
	CON	POS	FS	FB	SB			CON vs. B	POS vs. F	POS vs. SB	FS vs. FB
DM, %/h	2.9	3.6	3.2	2.7	3.3	0.44	0.46	0.49	0.15	0.49	0.37
NDF, %/h	3.2	3.5	3.2	2.8	3.2	0.47	0.82	0.93	0.32	0.65	0.52
ADF, %/h	3.1	3.4	3.1	2.5	3.0	0.57	0.72	0.91	0.32	0.59	0.34
CP ^e											
Soluble, %	35.1	34.9	35.2	31.9	34.8	0.77	0.01	0.24	0.12	0.93	0.01
Slowly degradable, %	35.2	34.0	33.4	39.7	39.5	2.07	0.01	0.33	0.12	0.01	0.01
Degradation rate, %/h	3.7	3.9	3.6	3.4	3.7	0.37	0.59	0.81	0.13	0.55	0.57
Extent of degradability, %	70.3	68.9	68.6	71.6	74.2	1.81	0.04	0.74	0.47	0.01	0.13

^aCON = no block, POS = 341 g (DM basis) of control block offered per steer daily, FS = 341 g of control block offered plus 2 g of fermentation extract bolused directly into rumen via gelatin capsule per steer daily, FB = 341 g of block containing fermentation extract offered per steer, and SB = 341 g of block containing seaweed meal offered per steer daily.

^bCON vs. B = no block vs. all blocks, POS vs. F = control block vs. fermentation block and fermentation extract provided separately, POS vs. SB = control block vs. seaweed block, and FS vs. FB = fermentation extract provided separately vs. fermentation block.

^cn = 5 observations per treatment.

^dProbability value for the *F*-test of overall treatment.

^ea + b (1 - e^{-kt}), where a = fraction degraded at time 0, b = slowly degraded fraction, k = rate, and t = time (Ørskov and McDonald, 1979). Not corrected for microbial CP.

Table 6. Effect of cooked molasses block supplementation on total ruminal fill, ruminal DM fill, and fluid dilution rate in steers offered low-quality hay

Item	Block treatment ^a						SEM ^c	P-value ^d	Contrast ^b			
	CON	POS	FS	FB	SB	CON vs. B			POS vs. F	POS vs. SB	FS vs. FB	
Total ruminal fill, kg	62.2	62.5	68.7	63.3	65.9	2.86	0.34	0.10	0.08	0.15	0.02	
Ruminal DM fill, kg	10.7	10.6	11.7	11.6	11.2	0.38	0.60	0.16	0.04	0.31	0.95	
g/kg BW	28.8	29.1	32.9	32.8	30.4	1.31	0.09	0.08	0.02	0.47	0.94	
Fluid dilution rate, %/h	10.9	10.0	9.9	8.8	11.0	0.68	0.08	0.23	0.44	0.33	0.29	

^aCON = no block, POS = 341 g (DM basis) of control block offered per steer daily, FS = 341 g of control block offered plus 2 g of fermentation extract bolused directly into rumen via gelatin capsule per steer daily, FB = 341 g of block containing fermentation extract offered per steer, and SB = 341 g of block containing seaweed meal offered per steer daily.

^bCON vs. B = no block vs. all blocks, POS vs. F = control block vs. fermentation block and fermentation extract provided separately, POS vs. SB = control block vs. seaweed block, and FS vs. FB = fermentation extract provided separately vs. fermentation block.

^cn = 5 observations per treatment.

^dProbability value for the *F*-test of overall treatment.

of seaweed meal in the blocks increased total tract digestion of OM and CP. Cooked molasses blocks are suitable as a protein source for cattle consuming low-quality forages.

Literature Cited

- Allen, V. G., K. R. Pond, K. E. Saker, J. P. Fontenot, C. P. Bagley, R. L. Ivy, R. R. Evans, R. E. Schmidt, J. H. Fike, X. Zhang, J. Y. Ayad, C. P. Brown, M. F. Miller, J. L. Montgomery, J. Mahan, D. B. Wester, and C. Melton. 2001. Tasco: Influence of a brown seaweed on antioxidants in forages and livestock—A review. *J. Anim. Sci.* 79(Suppl. E):E21–E31.
- AOAC. 1990. Official Methods of Analysis. Vol. I. 15th ed. Assoc. Off. Anal. Chem., Arlington, VA.
- Bailey, D. W., and G. R. Welling. 1999. Modification of cattle grazing distribution with dehydrated molasses supplement. *J. Range Manage.* 52:575–582.
- Broderick, G. A., and J. H. Kang. 1980. Automated simultaneous determination of ammonia and total amino acids in ruminal fluid and in vitro media. *J. Dairy Sci.* 63:64–75.
- Carey, D. A., J. S. Caton, and M. Biondini. 1993. Influence of energy source on forage intake, digestibility, in situ forage degradation, and ruminal fermentation in beef steers fed medium-quality brome hay. *J. Anim. Sci.* 71:2260–2269.
- DelCurto, T., R. C. Cochran, L. R. Corah, A. A. Beharka, E. S. Vanzant, and D. E. Johnson. 1990a. Supplementation of dormant tallgrass-prairie forage: II. Performance and forage utilization characteristics in grazing beef cattle receiving supplements of different protein concentrations. *J. Anim. Sci.* 68:532–542.
- DelCurto, T., R. C. Cochran, D. L. Harmon, A. A. Beharka, K. A. Jacques, G. Towne, and E. S. Vanzant. 1990b. Supplementation of dormant tallgrass-prairie forage: I. Influence of varying supplemental protein and (or) energy levels on forage utilization characteristics of beef steers in confinement. *J. Anim. Sci.* 68:515–531.
- Fenton, T. W., and M. Fenton. 1979. An improved procedure for the determination of chromic oxide in feed and feces. *Can. J. Anim. Sci.* 59:631–634.
- Fike, J. H., V. G. Allen, R. E. Schmidt, X. Zhang, J. P. Fontenot, C. P. Bagley, R. L. Ivy, R. R. Evans, R. W. Coelho, and D. B. Wester. 2001. Tasco-Forage: I. Influence of a seaweed extract on antioxidant activity in tall fescue and in ruminants. *J. Anim. Sci.* 79:1011–1021.
- Firkins, J. L., W. P. Weiss, M. L. Eastridge, and B. L. Hull. 1990. Effects of feeding fungal culture extract and animal-vegetable fat on degradation of hemicellulose and on ruminal bacterial growth in heifers. *J. Dairy Sci.* 73:1812–1822.
- Freeman, A. S., M. L. Galyean, and J. S. Caton. 1992. Effects of supplemental protein percentage and feeding level on intake, ruminal fermentation, and digesta passage in beef steers fed prairie hay. *J. Anim. Sci.* 70:1562–1572.
- Goetsch, A. L., and M. L. Galyean. 1983. Influence of feeding frequency on passage of fluid and particulate markers in steers fed a concentrate diet. *Can. J. Anim. Sci.* 63:727–730.
- Goering, H. K., and P. J. Van Soest. 1970. Forage Fiber Analyses (Apparatus, Reagents, Procedures, and Some Applications). Agric. Handbook No. 379. ARS-USDA, Washington, DC.
- Gomez-Alarcon, R. A., D. Dudas, and J. T. Huber. 1990. Influence of cultures of *Aspergillus oryzae* on rumen and total tract digestibility of dietary components. *J. Dairy Sci.* 73:703–710.
- Greenwood, R. H., E. C. Titgemeyer, and J. S. Drouillard. 2000. Effects of base ingredient in cooked molasses blocks on intake and digestion of prairie hay by beef steers. *J. Anim. Sci.* 78:167–172.
- Greenwood, R. H., E. C. Titgemeyer, C. A. Löest, and J. S. Drouillard. 1998. Effects of supplement strategy on intake and digestion of prairie hay by beef steers and plasma amino acid concentrations. *Prof. Anim. Sci.* 14:56–61.
- Heldt, J. S., R. C. Cochran, C. P. Mathis, B. C. Woods, K. C. Olson, E. C. Titgemeyer, T. G. Nagaraja, E. S. Vanzant, and D. E. Johnson. 1999. Effects of level and source of carbohydrate and level of degradable intake protein on intake and digestion of low-quality tallgrass-prairie hay by beef steers. *J. Anim. Sci.* 77:2846–2854.
- Humphry, J. B., K. P. Coffey, J. L. Moyer, F. K. Brazle, and L. W. Lomas. 2002. Intake, digestion, and digestive characteristics of *Neotyphodium coenophialum*-infected and uninfected fescue by heifers offered hay diets supplemented with *Aspergillus oryzae* fermentation extract of laidlomycin propionate. *J. Anim. Sci.* 80:225–234.
- Köster, H. H., R. C. Cochran, E. C. Titgemeyer, E. S. Vanzant, I. Abdelgadir, and G. St-Jean. 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. *J. Anim. Sci.* 74:2473–2481.
- Löest, C. A., E. C. Titgemeyer, J. S. Drouillard, B. D. Lambert, and A. M. Trater. 2001. Urea and biuret as nonprotein nitrogen sources in cooked molasses blocks for steers fed prairie hay. *Anim. Feed Sci. Technol.* 94:115–126.
- Mathis, C. P., R. C. Cochran, J. S. Heldt, B. C. Woods, I. E. O. Abdelgadir, K. C. Olson, E. C. Titgemeyer, and E. S. Vanzant. 2000. Effects of supplemental degradable intake protein on utilization of medium- to low-quality forages. *J. Anim. Sci.* 78:224–232.
- Mertens, D. R., and J. R. Loften. 1980. The effects of starch on forage fiber digestion kinetics in vitro. *J. Dairy Sci.* 63:1437–1446.
- Olson, K. C., R. C. Cochran, T. J. Jones, E. S. Vanzant, E. C. Titgemeyer, and D. E. Johnson. 1999. Effects of ruminal administration of supplemental degradable intake protein and starch on utilization of low-quality warm-season grass hay by beef steers. *J. Anim. Sci.* 77:1016–1025.

- Ørskov, E. R., and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *J. Agric. Sci. (Camb.)* 92:499–503.
- Robertson, J. B., and P. J. Van Soest. 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74:3583–3597.
- Sunvold, G. D., R. C. Cochran, and E. S. Vanzant. 1991. Evaluation of wheat middlings as a supplement for beef cattle consuming dormant bluestem-range forage. *J. Anim. Sci.* 69:3044–3054.
- Toppo, S., A. K. Verma, R. S. Dass, and U. R. Mehra. 1997. Nutrient utilization and rumen fermentation pattern in crossbred cattle fed different planes of nutrition supplemented with urea molasses mineral block. *Anim. Feed Sci. Technol.* 64:101–112.
- Uden, P., P. E. Colucci, and P. J. Van Soest. 1980. Investigation of chromium, cerium, and cobalt as markers in digesta. Rate of passage studies. *J. Sci. Food Agric.* 31:625–632.
- Zinn, R. A., and F. N. Owens. 1986. A rapid procedure for purine measurement and its use for estimating net ruminal protein synthesis. *Can. J. Anim. Sci.* 66:157–166.