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A. M. Gehman
University of Nebraska-Lincoln, agehman2@unl.edu

J. A. Bertrand
Clemson University

T. C. Jenkins
Clemson University

B. W. Pinkerton
Clemson University

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The Effect of Carbohydrate Source on Nitrogen Capture in Dairy Cows on Pasture[1]

A. M. Gehman,* J. A. Bertrand,†[2] T. C. Jenkins,† and B. W. Pinkerton‡
*Animal Science Department, University of Nebraska, Lincoln 68583
†Department of Animal and Veterinary Science, and
‡Agriculture and Natural Resources, Clemson University, Clemson, SC 29634

ABSTRACT

The objective of this study was to determine if feeding carbohydrate supplements with faster degradation rates than corn to dairy cows grazing ryegrass would improve nitrogen capture, milk production, and components. Treatments were grain supplements based on: 1) corn (CORN), 2) barley and molasses (BM), or 3) citrus pulp and molasses (CM). For BM and CM, the diet composition was the same as that of CORN except that a portion of the corn was replaced with barley and molasses or citrus pulp and molasses, respectively, on a dry matter basis. Cows grazed ryegrass (*Lolium multiflorum* Lam.) pasture. Yield of milk, 3.5% fat-corrected milk, energy-corrected milk, and milk fat, as well as milk fat percentage, were not different among treatments. True milk protein percentage was higher for CORN (2.81%) compared with CM (2.70%), but was not different for BM (2.77%). However, true milk protein yield was not different among treatments. Milk urea N was higher for BM (11.43 mg/dL) compared with both CORN and CM (average: 9.95 mg/dL). There were no differences among CORN, BM, and CM treatments for overall BUN (average: 10.60 mg/dL). At 0400 h, however, cows on CORN had higher BUN than cows on CM (11.43 vs. 9.96 mg/dL), but there were no differences between CORN and BM (average: 11.21 mg/dL) or BM and CM (average: 10.48 mg/dL), and there were no differences among treatments at other time points. The CM diet might have shown more advantage if the pasture crude protein content was higher. Partial replacement of corn with citrus pulp for grazing cows should be further studied using pasture with higher crude protein content. Although cows receiving CM and BM did not produce more milk than cows on CORN, if barley or citrus pulp is less expensive than corn, they may be viable replacements for a portion of the corn supplement for grazing cows.

Key words: nitrogen capture, pasture, barley, citrus pulp

INTRODUCTION

Interest in utilizing pasture as a primary forage source for dairy cows has been renewed in recent years. Maintaining dairy cows on pasture is associated with reduced financial inputs, reduced instances of diseases such as mastitis, ketosis, and dystocia, and increased levels of conjugated linoleic acid (**CLA**), a known anticarcinogen found only in ruminant food products.

Lush pasture has a high rate of CP degradation in the rumen (Van Vuuren et al., 1991). One of the challenges of utilizing pasture is maximizing ruminal N capture. Van Vuuren et al. (1991) found that N in ryegrass degrades at a rate of 9 to 14%/h, whereas pasture OM, composed mostly of structural carbohydrates, degrades at a rate of 7%/h, creating an asynchronous relationship between protein and energy availability for rumen microbial protein synthesis. This inefficient N capture can result in high ruminal ammonia, BUN, and MUN in cows grazing pasture. Blood urea N and MUN levels greater than 20 mg/dL have been associated with low pregnancy rates. There is also an energetic expenditure for urea synthesis. Using the Cornell Net Carbohydrate and Protein System model, Kolver and Muller (1998) predicted a 1.8-kg/d reduction in milk production due to urea synthesis for cows consuming pasture.

Beever et al. (1986) found that N in ryegrass pasture degraded in the rumen at a rate of 13 to 14%/h with 6.4 to 11.7% instantly degradable and 89.3 to 92.9% potentially degradable. Theoretically, a carbohydrate source with a degradation rate of 13 to 14%/h would be the best choice to optimize N capture when cows are grazing grass pasture. The starch in corn, the most common starch source fed to dairy cattle, degrades at a rate of approximately 4.0 to 6.4%/h (Herrera-Saldana et al., 1990; Tamminga et al., 1990), which is considerably slower than the degradation rate of pasture protein.

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[2] Corresponding author: jbrtrnd@clemson.edu

Carbohydrate sources that degrade at faster rates than corn may result in higher rates of microbial ammonia capture and improved efficiency. The starch content of barley degrades at a much faster rate in the rumen (14.7 to 24.5%/h; Herrera-Saldana et al., 1990; Tamminga et al., 1990) than starch from corn. Hall et al. (1998) reported that citrus pulp contains 34.5% neutral detergent-soluble fiber, most of which is pectin that degrades at a rate of 13%/h, similar to the degradation rate of pasture N. In addition, the NDF component of citrus pulp is 20.5%, is highly digestible, and degrades at a rate of 15%/h (Hall et al., 1998). A partial replacement of corn with barley and molasses (a rapidly degraded carbohydrate), or citrus pulp and molasses should provide a more synchronized supply of carbohydrates and N for grazing dairy cows than a supplement with corn as the only grain source.

The objective of this experiment was to evaluate the partial replacement of corn with barley and molasses or citrus pulp and molasses as supplements for grazing cows. The effects of carbohydrate source on nitrogen capture and milk yield and components including CLA were examined.

MATERIALS AND METHODS

Cows and Treatments

Eleven multiparous and 3 primiparous Holstein cows [BW: 603 ± 49 kg; BCS: 2.6 ± 0.6; milk yield: 41.1 ± 7.7 kg/d; parity: 2.1 ± 0.8; DIM: 130 ± 27 (mean ± SD)] from Clemson University's LaMaster Dairy Center (Clemson, SC) were used in a 9-wk trial to study the effect of carbohydrate source on nitrogen capture in dairy cows grazing annual ryegrass pasture (*Lolium multiflorum* Lam.). There were originally 15 cows in the study, but 1 cow died during the experiment from a condition not related to the study. The experiment was conducted during the spring of 2004 (March 24 to May 28). Experimental procedures were approved by Clemson University's Animal Research Committee.

Cows were allocated to 2 groups of 5 and 1 group of 4 based on milk production, and then randomly assigned to 1 of 3 dietary treatments within a 3 × 3 Latin square design with three 21-d periods. Treatments were grain supplements based on 1) dry ground corn (**CORN**), 2) rolled barley and molasses (**BM**), or 3) citrus pulp and molasses (**CM**). For BM and CM, diet composition was the same as CORN except that a portion of the dry ground corn was replaced with rolled barley and molasses or citrus pulp and molasses on a DM basis. Supplements were formulated to be isonitrogenous and isoenergetic. Ingredient composition of the supplements is shown in Table 1.

Table 1. Ingredient composition of supplements

Ingredient composition, % of DM	Treatment[1]		
	CORN	BM	CM
Dry ground corn	61.4	26.3	26.3
Rolled barley	—	26.3	—
Citrus pulp	—	—	26.3
Molasses	—	8.8	8.8
Cottonseed hulls	10.1	10.1	10.1
Whole cottonseed	11.8	11.8	11.8
Soybean hulls	6.0	6.0	6.0
Soybean meal	5.9	5.9	5.9
Magnesium oxide	0.3	0.3	0.3
Salt	0.7	0.7	0.7
Sodium bicarbonate	0.6	0.6	0.6
Zinpro 4-plex[2]	0.3	0.3	0.3
Dynamate[3]	0.3	0.3	0.3
Limestone	1.9	1.9	1.9
Dicalcium phosphate	0.4	0.4	0.4
Vitamin mix[4]	0.3	0.3	0.3

[1] Treatments were grain supplements based on dry ground corn (CORN), rolled barley and molasses (BM), or citrus pulp and molasses (CM).

[2] 0.18% Co, 0.88% Cu, 1.40% Mn, and 3.58% Zn (Zinpro Corp., Eden Prairie, MN).

[3] Guaranteed analysis of at least 22.0% S, 18.0% K, and 11.0% Mg (The Mosaic Company, Lake Forest, IL).

[4] Guaranteed analysis of at least 12.05% Ca, 0.02% Se, 0.06% Co, 1.15% Cu, 0.05% I, 0.01% Fe, 2.90% Mn, 0.85% vitamin A, 0.22% vitamin D, 2.76% vitamin E (Newberry Feed, Newberry, SC).

Pasture was seeded with ryegrass on October 6, 2003, and N fertilizer was applied at a rate of 67.3 kg/ha in February 2004. When the experiment commenced, paddock size was allocated as to provide 17 kg of DM/cow per d. Sward DM availability was determined by collecting pasture samples from 9 areas in a section and drying the samples in a microwave oven (Heinrichs and Ishler, 2000). Approximately 50 g of pasture was heated on high in a microwave oven until it reached a constant weight (approximately 5 min). The size of the paddock was adjusted as needed to provide 17 kg of DM/cow per d. New paddocks were constructed following the a.m. milking using temporary polywire. The walking distance from the pasture to the milking parlor averaged 0.4 km (range: 0.25 to 0.5 km). Cows had access to ryegrass pasture from 0830 to 1530 h and from 1730 to 0630 h. Cows had ad libitum access to water while in the pasture.

Cows were milked at 0700 and 1600 h and fed the supplement individually in equal parts immediately after milking using Calan gates (American Calan, Inc., Northwood, NH). Cows were given approximately 1 h to consume their supplement before returning to pasture. Supplement was fed at a rate of 1 kg of grain per 4 kg of milk (Bargo et al., 2002a) based on pretrial milk production.

Experimental Measures and Sample Analysis

During each of the three 21-d periods, d 1 to 17 were used to adjust the cows to the dietary treatments, and d 18 to 21 were used for sample collection. Cows were weighed for 2 consecutive days on d 0 and 1 of the first period, then on d 19 and 20 of each period; weights from consecutive days were averaged. Body weight change was calculated as the difference between the BW at the end of the period and BW at the beginning of the period.

Samples of supplements were collected on d 19 and ground through a 1-mm screen (Wiley Mill, Thomas Scientific, Philadelphia, PA) before analysis. On d 21, pasture samples were hand-plucked to the approximate height at which the cows grazed. One pasture sample was frozen with liquid nitrogen to immediately halt cellular activity and was used to determine fatty acid content. An additional sample was taken without liquid nitrogen and used to determine nutrient content. Both samples were immediately placed in the freezer, lyophilized, and ground through a 1-mm screen. Supplement and pasture samples were analyzed for DM and ash (AOAC, 1990), ADF, NDF, and lignin (Fiber Analyzer 200, Ankom Technology Corp., Fairport, NY), in vitro DM digestibility (**IVDMD**; Ankom Daisy II), CP (AOAC, 1990), soluble protein (Krishnamoorthy et al., 1982), minerals (P, K, Ca, Mg, S, Zn, Cu, Mn, Fe, and Na; Haynes, 1980), and starch (YSI 2700 Select Biochemistry Analyzer, YSI Inc., Yellow Springs, OH).

For fatty acid analysis, pasture samples were methylated (Kramer et al., 1997) and analyzed using a Hewlett Packard 5890A GLC (Agilent Technologies, Palo Alto, CA). Fatty acid methyl esters were separated on a 30 m × 0.25 mm × 0.2 μm (film thickness) fused silica capillary column (P-2380, Supelco Inc., Bellefonte, PA). Helium was the carrier gas, and flow rate was 20 cm/s. A flame-ionization detector and a model 7673 autoinjector were used. The injector temperature was 250°C, and the detector temperature was 260°C. The initial column temperature was 140°C for 3 min, and then increased to 220°C at a rate of 3.7°C/min. Final temperature of 220°C was maintained for 20 min. Peaks were quantified by peak area comparisons with a known amount of an internal standard (2 mg of heptadecanoic acid; Sigma Chemical Co., St. Louis, MO).

For BUN determination, blood samples were collected on d 21 at 0800, 1200, 1600, 2000, 2400 h, and on d 1 at 0400 h into tubes with no additive. Samples were centrifuged (Sorvall RC-5B Refrigerated Superspeed Centrifuge, DuPont Instruments, Wilmington, DE) at 1,000 × g and 4°C for 15 min. Serum was collected, frozen, and then thawed and used for BUN analysis (Stanbio Laboratory, Inc., Boerne, TX).

From d 12 to 21, cows were orally dosed twice daily at approximately 0800 and 1600 h with gelatin capsules (Torpac Inc., Fairfield, NJ) containing 10 g of Cr_2O_3. Fecal grab samples were collected at 0800, 1200, 1600, 2000, 2400 h on d 21 and at 0400 h on d 1 of the next period, and immediately frozen. Fecal samples were thawed, composited by cow for each period, dried at 55°C, then ground (Cyclotec Sample Mill, Foss-Tecator, Hoganas, Sweden) to a 1-mm particle size. Fecal samples were analyzed for Cr using a DU-64 atomic absorption spectrometer (Beckman Instruments, Fullerton, CA). Fecal Cr concentration was used to calculate fecal output as follows: fecal output = (g of Cr dosed per d)/(g of Cr/g of fecal DM). Total DMI was estimated using the equation: DMI = fecal output/(1 – IVDMD). Initially, total DMI was calculated using the average IVDMD between pasture and supplements. Pasture intake was determined by subtracting supplement DMI from total DMI. Once pasture DMI was determined, a weighted mean for IVDMD was calculated and corrected values for total and pasture DMI were calculated (Holden et al., 1995).

Milk production was averaged by cow for d 17 to 21 for each period. Milk samples were collected on d 18 to 20 during 4 consecutive milkings. One aliquot from each milking was preserved in 2-bromo-2-nitropane-1,3-diol and analyzed for milk fat, protein, and MUN (Fossomatic 4000, Foss Foods Technology, Eden Prairie, MN) and SCC (Foss 300, Foss Foods Technology) at Universal DHIA (Blacksburg, VA). Results were averaged for each cow each period. An additional aliquot from each milking was retained without preservative and immediately frozen for CLA analysis. For CLA analysis, samples were composited by cow for each period, methylated, and analyzed for fatty acids by GLC using the same method used for feed samples except column temperature was 50°C for 2 min, then increased to 250°C at a rate of 4.5°C/min, and held at 250°C for 15 min; no internal standard was used.

Statistical Analyses

Data were analyzed by least squares ANOVA using the mixed procedure of SAS (SAS Institute, 2003). The data for milk yield, milk components, and DMI were analyzed as a Latin square design and the model included the effects of group, cow within group, period, treatment, the interaction of period, treatment, and cow within group, and the residual error. The error term used for the main effect of treatment was the interaction of period by treatment by cow within group. The data for BUN were analyzed by a split-plot design and the model included the effects of group, cow within group, period, treatment, the interaction of period, treatment,

Table 2. Nutrient composition of ryegrass pasture and supplements

	Pasture			Supplement[1]		
Item	Period 1	Period 2	Period 3	CORN	BM	CM
DM, %	23.8	26.0	30.6	89.1	89.4	89.4
	(% of DM)					
OM	92.5	93.7	92.7	94.8	93.7	93.3
CP	15.6	16.4	17.5	12.4	14.1	12.2
Soluble protein (% of CP)	56.1	62.8	61.4	23.4	31.0	29.1
Starch	1.6	2.3	1.5	38.6	29.2	20.3
NDF	40.0	49.8	52.7	23.7	30.9	28.6
ADF	19.9	25.7	28.7	13.7	17.6	18.5
Lignin	1.9	3.7	3.6	3.6	4.8	4.5
Ether extract[2]	6.0	4.1	3.7	5.2	4.9	4.7
Total fatty acids	5.0	3.1	2.7	4.2	3.9	3.7
NFC[3]	30.9	23.4	18.8	53.5	43.8	47.8
In vitro DM digestibility	91.8	83.9	78.0	87.8	85.0	87.1
Ca	0.49	0.46	0.56	1.13	1.26	1.66
P	0.30	0.28	0.34	0.57	0.62	0.50
Mg	0.23	0.26	0.26	0.42	0.54	0.44
K	2.94	2.38	2.74	0.65	1.17	1.27
S	0.28	0.33	0.29	0.19	0.29	0.28
Zn (ppm)	39	48	57	254	266	215
Cu (ppm)	6	7	7	67	80	78
Mn (ppm)	76	46	46	158	178	157
Fe (ppm)	98	85	103	314	381	634

[1] Supplements were based on dry ground corn (CORN), rolled barley and molasses (BM), or citrus pulp and molasses (CM).

[2] Ether extract = total fatty acids + 1 (NRC, 2001).

[3] NFC = 100 − (CP + NDF + ether extract + ash).

and cow within group, time, the interaction of time and group, the interaction of time and period, the interaction of time and treatment, the interaction of time, period, treatment, and cow within group, and the residual error. The error term used for the main effect of treatment was the interaction of time by period by treatment by cow within group. Differences were significant if $P < 0.05$. Trends were denoted if $P < 0.1$.

RESULTS AND DISCUSSION

Diet Composition and Intake

The nutrient and fatty acid compositions of the pasture and experimental treatments are shown in Tables 2 and 3. Dry matter intakes are shown in Table 4.

Muller and Fales (1998) reported a range in CP of cool-season grass pasture to be from 18 to 25%, whereas Van Vuuren et al. (1991) found a range in CP for ryegrass of 15.6 to 29.8% with an average CP of 24.3%. In this experiment, CP values were lower (15.6 to 17.5% DM). Pasture CP also increased slightly as the growing season progressed, instead of decreasing as expected (Van Vuuren et al., 1991). Climatic factors, such as rainfall and temperature at the time of fertilization, could have affected nitrogen volatilization, leaching, and growth rate, and therefore, pasture CP content (Carruthers and Neil, 1997). Soluble protein in this experiment was also higher (56.1 to 62.8% of CP) than that reported by Muller and Fales (1998; 15 to 35% of CP).

Neutral detergent fiber (40.0 to 52.7%) was similar to that reported by Muller and Fales (1998; 40 to 55%), and by Van Vuuren et al. (1991; 34.1 to 49.3%), with a general increase as time progressed. Acid detergent fiber levels in period 1 of this experiment were lower (19.9%) than that reported by Muller and Fales (1998; 24 to 34%), but were within range for periods 2 and 3 (25.7 and 28.7%). Except for period 3, pasture NFC content (18.8 to 30.9%) exceeded the range reported by Muller and Fales (1998; 12 to 20%), but followed the same trend of decreasing with time.

Pasture IVDMD values for this experiment averaged 84.6% (range 78.0 to 91.8%), being higher than published values but following a decreasing trend as the pasture matured. Holden et al. (1994b) estimated the apparent DM digestibility for cool-season grass to be 64%, and Kolver and Muller (1998) estimated the IVDMD of a sward composed of 53% ryegrass to be 77%.

Supplement intake was not different across treatments, but pasture intake tended ($P < 0.10$) to be lower for cows on BM (13.7 kg/d) than for cows on CORN (15.9 kg/d) or CM (16.1 kg/d). This resulted in a trend ($P < 0.10$) for a difference in total DMI among treatments with cows on BM (22.8 kg/d) tending to be lower than

Table 3. Composition of specific fatty acids (FA) in pasture and supplements

FA	Pasture			Supplement[1]		
	Period 1	Period 2	Period 3	CORN	BM	CM
	(mg of FA/g of feed)					
C16:0	8.19	6.23	4.82	18.91	21.29	22.08
C18:0	0.78	0.88	1.13	2.59	2.52	2.79
C18:1	1.46	2.86	2.51	19.52	16.97	17.44
C18:2	8.89	13.35	15.88	53.95	52.05	49.35
C18:3	39.93	40.47	36.91	0.99	1.85	1.68
Other[2]	40.76	36.20	38.75	4.03	5.32	6.67
Total, mg	41.05	24.86	23.87	41.24	37.25	34.47

[1] Supplements were based on dry ground corn (CORN), rolled barley and molasses (BM), or citrus pulp and molasses (CM).

[2] Other = C15:0, C16:1, C20:0, C20:3, C22:0, C24:0, and unidentified FA.

for cows on CORN or CM (25.0 or 25.2 kg/d). Intakes of CP and NDF were not different among treatments (Table 4). Intake of ADF was lower ($P < 0.05$) for cows on BM than for cows on CM, because total intake tended to be lower for cows on BM, and because CM contained the highest ADF level (Table 2). Body weights and BW change did not differ among treatments (Table 4).

Total DMI was slightly higher than that found by Holden et al. (1994a); however, greater amounts of concentrate were fed in this experiment. High DMI estimation may be due to overestimation of DMI by the Cr_2O_3 technique. Holden et al. (1994b) found that the Cr_2O_3 technique overestimates DMI by 10%. If DMI are reduced by 10%, they are similar to values computed using Equation 1-2 of NRC (2001) based on milk production and BW. High estimated DMI may also be due to high IVDMD values found for pasture in this experiment (Table 2). Pasture DMI was lower than that found by Kolver and Muller (1998) for cows consuming only pasture (19.0 kg/d), but pasture intake decreases when concentrates are fed (Bargo et al., 2002a). Bargo et al. (2002a) found a 4.4-kg/d decrease in pasture DMI when

Table 4. Least squares means for nutrient intakes, milk production and components, and BW

	Treatment[1]			
	CORN	BM	CM	SEM
Intake				
Pasture intake, kg/d	15.9^{y}	13.7^{z}	16.1^{y}	2.00
Supplement intake, kg/d	9.2	9.1	9.2	1.08
Total DMI, kg/d	25.0^{y}	22.8^{z}	25.2^{y}	2.29
Total CP intake, kg/d	3.7	3.5	3.7	0.16
Total NDF intake, kg/d	9.4	9.1	9.9	0.41
Total ADF intake, kg/d	5.0^{ab}	4.8^{a}	5.4^{b}	0.21
Milk yield (kg/d)	30.6	29.9	30.0	3.44
Efficiency (kg of milk/kg of DMI)	1.25	1.33	1.24	0.05
FCM[2] (kg/d)	28.9	28.6	28.5	2.42
FCM efficiency (kg of milk/kg of DMI)	1.18	1.27	1.19	0.04
ECM[3] (kg/d)	31.3	31.0	30.9	1.74
ECM efficiency (kg of milk/kg of DMI)	1.29^{y}	1.40^{z}	$1.30^{y,z}$	0.04
Fat (%)	3.20	3.27	3.26	0.15
Fat yield (kg/d)	0.95	0.91	0.96	0.10
Protein (%)	2.81^{a}	2.77^{ab}	2.70^{b}	0.08
Protein yield (kg/d)	0.83	0.78	0.80	0.08
MUN (mg/dL)	10.05^{a}	11.43^{b}	9.85^{a}	0.42
BUN (mg/dL)	10.62	10.99	10.19	0.53
BW, kg	606.4	605.5	606.9	14.9
BW change, kg	–3.2	–2.02	–3.5	2.90

[a,b] Least squares means in the same row with different superscripts differ ($P < 0.05$).

[y,z] Least squares means in the same row with different superscripts differ ($P < 0.10$).

[1] Treatments were grain supplements based on dry ground corn (CORN), rolled barley and molasses (BM), or citrus pulp and molasses (CM).

[2] 3.5% FCM = (0.4255 × kg of milk) + [16.425 (% fat/100) × kg of milk].

[3] ECM = (0.3246 × kg of milk) + (12.86 × kg of fat) + (7.04 × kg of protein)

concentrates were fed at the same level as this experiment (1 kg of concentrate/4 kg of milk). If that decrease is taken into account, pasture intakes in this experiment were similar to those of Kolver and Muller (1998).

Fiber-based concentrates may have advantages over starch-based concentrates when fed to grazing cows by increasing DMI. When early-lactation cows grazed ryegrass pasture, pasture and total DMI were increased 0.7 (Meijs, 1986) and 0.8 kg/d (Sayers et al., 2003) when fiber-based concentrates replaced starch-based concentrates. Bargo et al. (2003) suggested that replacing starch-based concentrates with fiber-based concentrates would increase rumen pH, enhance pasture digestion, and result in higher DMI. Pasture and total DMI were similar with both types of concentrates for late-lactation cows grazing orchardgrass (Delahoy et al., 2003). Although there are a low number of studies, Bargo et al. (2003) reported that, overall, fiber-based concentrates slightly increased DMI by 0.13 kg/d, but there was large variation among studies, ranging from –0.7 to 1.4 kg/d.

Milk Production and Composition

Treatments had no effect on yield of milk, 3.5% FCM, or ECM, or on milk fat percentage or yield (Table 4). Milk yields were similar to those reported by Bargo et al. (2002b; 28.5 kg/d), for cows on pasture fed a supplement composed of 60% dry ground corn in early to mid-lactation. Milk protein percentage was higher ($P > 0.05$) for cows on CORN compared with cows on CM (2.81 vs. 2.70%). Delahoy et al. (2003) also reported higher milk protein content in milk from grazing cows supplemented with ground corn compared with supplementation of nonforage fiber sources (beet pulp, soybean hulls, and wheat middlings; 3.23 vs. 3.19%). Khalili and Sairanen (2000) found no differences in milk protein percentage for grazing cows with no supplement or supplemented with barley or a mixture of concentrate sources that included nonforage fiber (wheat bran and molasses sugar beet pulp; 3.42 vs. 3.43 or 3.49%). However, protein yield was lower for cows on pasture only compared with cows fed barley, which was lower than that for cows fed nonforage fiber (0.61 vs. 0.67 and 0.73 kg/d) because of the lower milk yield.

Meijs (1986) also reported increased milk production when fiber-based concentrates of beet pulp and soybean hulls replaced corn and cassava. Two other grazing studies, however, reported similar milk yields (Delahoy et al., 2003; Sayers et al., 2003) and others reported reduced milk yield (Valk et al., 1990). Overall, Bargo et al. (2003) reported that milk production was slightly reduced across published studies (–0.46 kg/d) when fiber-based concentrates replaced starch-based concentrates for grazing dairy cattle, but the milk response ranged from –2.6 to 1.3 kg/d.

Table 5. Least squares means for milk fatty acids (FA)

FA	Treatment[1] CORN	BM	CM	SEM
	(g/100 g of FA)			
C4:0	3.30	3.26	3.28	0.14
C6:0	1.89	1.86	1.84	0.06
C8:0	1.18	1.15	1.12	0.04
C10:0	2.45^{a}	2.37^{ab}	2.29^{b}	0.07
C12:0	2.62^{a}	2.57^{ab}	2.43^{b}	0.07
C14:0	9.76	9.79	9.62	0.14
C14:1	1.37	1.44	1.37	0.05
C15:0	1.06	1.10	1.11	0.04
C16:0	24.79	25.23	25.42	0.36
C16:1	1.13	1.20	1.18	0.07
C18:0	13.92	14.29	14.55	0.65
C18:1	22.00	21.83	21.42	0.41
Trans C18:1	2.74^{a}	2.39^{b}	2.86^{a}	0.16
C18:2	2.30	2.15	2.19	0.08
Cis-9, *trans*-11 conjugated linoleic acid (CLA)	0.63	0.63	0.61	0.03
Trans-10, *cis*-12 CLA	0.08	0.08	0.07	0.02
C18:3	0.56^{a}	0.60^{a}	0.65^{b}	0.02
Other[2]	8.29	8.14	8.00	0.82

[a,b] Least squares means in the same row with different superscripts differ ($P < 0.05$).

[1] Treatments were grain supplements based on dry ground corn (CORN), rolled barley and molasses (BM), or citrus pulp and molasses (CM).

[2] Other = C17:0, C20:0, C20:3, C20:4, and unidentified FA.

Sayers et al. (2003) reported higher milk fat percentage with fiber-based concentrates compared with starch-based concentrates. Most studies, however, did not report changes in milk fat percentage (Meijs, 1986; Valk et al., 1990; Delahoy et al., 2003). In addition, Bargo et al. (2003) noted that replacing starch-based concentrates with fiber-based concentrates reduced milk protein –0.06 percentage units (range: –0.21 to 0.05 percentage units). In this study, partial replacement of corn with citrus pulp and molasses did not affect milk fat percentage or yield but did result in lower milk protein percentage (2.81 vs. 2.70%); neither were different from BM (2.77%).

In this study, cows consuming BM tended ($P < 0.10$) to have a greater efficiency of ECM yield than cows consuming CORN (1.40 vs. 1.29 kg of milk/kg of DMI), whereas there were no differences between CORN and CM (1.30 kg of milk/kg of DMI) or BM and CM ($P >$ 0.11). There were no differences among treatments for efficiency of milk or FCM yield.

Milk fatty acid profile is shown in Table 5. Fatty acids C10:0 and C12:0 were lower ($P < 0.05$) in milk from cows on CM compared with CORN. Milk from cows on CORN and CM was higher ($P < 0.05$) in *trans*-11 C18:1 than for cows on BM. *Trans*-11 C18:1 is an intermediate in the biohydrogenation of C18:2 and C18:3 (Bauman and Griinari, 2003). It can also be converted to *cis*-9, *trans*-11 C18:2, commonly known as CLA, by the action of stearoyl-CoA desaturase in the mammary gland.

Fatty acid C18:3 was higher ($P < 0.05$) in milk from cows on CM compared with milk from cows on CORN and BM. There were no differences among treatments for C4:0, C6:0, C8:0, C14:0, C14:1, C15:0, C16:0, C16:1, C18:0, C18:1, C18:2, *cis*-9, *trans*-11 CLA, *trans*-10, *cis*-12 CLA, or other fatty acids. Kelly et al. (1998) reported that cows consuming mostly ryegrass pasture produced milk with 1.09 g of CLA/100 g of fatty acid, whereas cows fed a TMR in confinement produced 0.49 g of CLA/100 g of fatty acid. Conjugated linoleic acid content in this experiment averaged 0.62 g/100 g of fatty acids and was slightly lower than levels reported by White et al. (2001) for Holstein cows grazing crabgrass and supplemented with a concentrate (0.72 g/100 g of fatty acids). Bargo et al. (2006) found that supplementation with a corn-based feed lowered milk CLA concentration compared with no supplementation (1.18 vs. 1.36 g/100 g of fatty acid), but the values reported were higher than those found in this study. Bargo et al. (2006) also found a tendency ($P = 0.07$) for cows supplemented with cracked corn to produce higher levels of CLA than those consuming steam-flaked corn (2.73 vs. 2.26 g/100 g of fatty acid) but found no differences when cows consumed ground corn or a nonforage fiber supplement (average: 2.85 g/100 g of fatty acids).

Nitrogen Capture

Blood urea N and MUN can be used as indicators of rumen N capture because these values are positively associated with rumen ammonia concentrations (DePeters and Ferguson, 1992). Data for BUN are shown in Figure 1. Average BUN did not differ among treatments (average: 10.60 mg/dL). As expected, there was an overall effect of time on BUN ($P < 0.05$); BUN was lower for cows on CM than for cows on CORN at 0400 h.

Blood urea N values for this study were lower than expected for cows on pasture supplemented with a carbohydrate source. Bargo et al. (2002b) reported BUN values of cows grazing high quality pasture while being supplemented with a corn-based concentrate to be 17.2 mg/dL, whereas Kolver et al. (1998) reported that BUN averaged 22.05 mg/dL for supplemented cows on pasture. Delahoy et al. (2003) found average BUN values of 13.1 mg/dL for cows supplemented with corn.

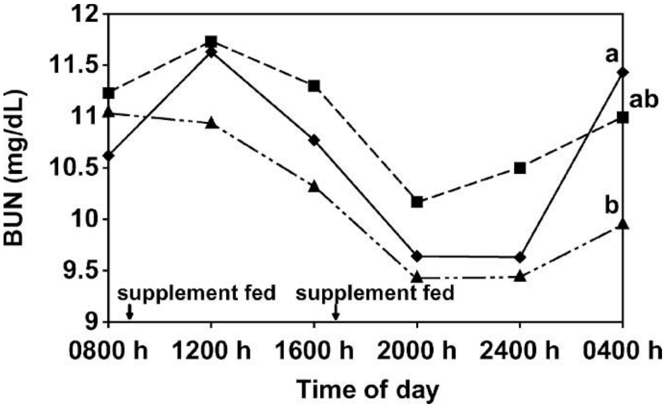

Figure 1. Diurnal changes in BUN for dairy cows grazing ryegrass and supplemented with corn (◆), barley and molasses (■), or citrus pulp and molasses (▲). Data points with different superscripts differ ($P < 0.05$).

Milk urea N was higher ($P < 0.05$) for cows on BM compared with cows on CORN and CM (Table 4). Similar to BUN values, MUN values were lower in this study than expected. Other research reported MUN values of supplemented cows on pasture to average 19 mg/dL (range 14.8 to 37.6 mg/dL; Khalili and Sairanen, 2000; Bargo et al., 2002b; Delahoy et al., 2003) with MUN values for cows on pasture only reported as high as 40 mg/dL (Khalili and Sairanen, 2000).

Although there were differences in MUN among treatments, no significant differences were found for BUN values. However, numeric differences among treatments for BUN followed a similar pattern as those seen for MUN values, with cows consuming CM having the lowest BUN and MUN values (10.19 and 9.85 mg/dL), followed by CORN (10.62 and 10.05 mg/dL) and BM (10.99 and 11.43 mg/dL). The reason for the conflicting findings is unknown; however, the small differences in N capture were not reflected in changes in milk production.

One of the strategies to improve efficiency of grazing cows is to match the rate of degradation of the pasture N with the rate of carbohydrate degradation from the supplement. Kolver et al. (1998) reported that peak ruminal ammonia concentrations were reduced 33% when grazing cows were fed concentrate synchronously with pasture rather than 4 h after pasture was fed.

Because the starch in barley degrades significantly faster than the starch in corn (24.5 vs. 4%/h), a partial replacement of corn with a barley and molasses mix should result in starch degradation that more closely matches the N degradation of pasture. García et al. (2000) reported that ruminal ammonia concentration was significantly reduced when heifers fed fresh forage were supplemented with barley compared with corn (19.4 vs. 26.9 mg/dL). Khalili and Sairanen (2000) found that barley supplementation did not reduce rumen ammonia levels in cows grazing pasture that was 20.9% CP compared with corn supplementation; however, it was reduced by feeding a combination of barley, oats, and beet pulp (28.7, 32.1, and 21.8 mg/dL for corn, barley, and barley/oats/beet pulp mix, respectively.) There were no differences in MUN between the concentrate mixture and barley (37.6 and 36.3 mg/dL), but both were significantly lower than MUN for corn (40.0 mg/dL). The grain mixture also increased yield of milk protein over corn or barley (0.73, 0.67, and 0.61 kg/d, respectively for mix, barley, and corn) as well as milk yield (21.0, 19.7, and 18.4 kg/d, respectively for mix, barley, and corn).

Because the neutral detergent-soluble fiber in citrus pulp is thought to degrade at similar rates as ryegrass pasture N (13%/h; Hall et al., 1998), partial replacement of corn for citrus pulp and molasses should offer an advantage. Miron et al. (2002) reported that partial replacement of corn by citrus pulp in TMR fed to high-producing dairy cows resulted in improved feed efficiency because the digestibility of neutral detergent soluble carbohydrates was higher for the diet with citrus pulp vs. the diet with corn. Fermentation of pectin is different from starch in that, although it is extensive, it produces little or no lactate and results in a higher acetate to propionate ratio than starch (Hall et al., 1998). Although other sources of nonforage fiber, including beet pulp, soybean hulls, and wheat middlings have been evaluated for grazing cattle (Delahoy et al., 2003), there is a lack of grazing studies that have evaluated citrus pulp as a supplement for grazing cows.

Few studies that considered replacement of starch-based concentrates with forage-based concentrates reported ruminal ammonia, BUN, or MUN. Delahoy et al. (2003) included nonforage fiber sources (beet pulp, soybean hulls, and wheat middlings) in addition to ground corn in a supplement for late-lactation grazing dairy cows and reported that the cows fed ground corn had lower MUN than cows fed the nonforage fiber concentrate (14.9 vs. 15.4 mg/dL). Plasma urea N, however, was not different between treatments.

In this study, partially replacing corn with barley and molasses did not improve the capture of ruminal N and in fact, resulted in higher MUN. Blood urea N, however, was not different across treatments. Feeding BM, however, did result in improved efficiency of ECM because pasture intake was lower but milk yield was not different. Partially replacing corn with CM did not improve milk yield or overall capture of pasture N, but BUN was reduced during one collection period compared with CORN. Milk protein content was lower for cows on CM than for cows on CORN but milk protein yield was not different. One of the reasons that treatment effects were minimized might have been the low CP content of the ryegrass pasture utilized in this experiment, which averaged 16.5%.

Bargo et al. (2002b) found BUN and MUN levels for cows consuming TMR with 16.9% CP content to average 13.8 and 10.6 mg/dL, respectively, whereas BUN and MUN levels for cows consuming pasture averaging 26.3% CP and a corn supplement were found to be 17.2 and 14.9 mg/dL, respectively. Blood urea N and MUN levels for cows on this trial were more similar to cows on TMR than to cows on pasture. If BM or CM improved nitrogen capture, the CP content of the pasture may not have been high enough to allow for detection of differences. Another explanation could be that the degradation of the corn in starch was more rapid than expected. Oba and Allen (2003) reported a degradation rate of 14%/h for the starch in corn, which is considerably higher than the 4%/h previously reported by Tamminga et al. (1990).

CONCLUSIONS

Partial replacement of corn with BM or CM did not offer advantages to cows grazing ryegrass pasture as measured by milk yield. Cows fed BM had higher MUN; however, cows on CM did have lower BUN during one collection period and may have shown more advantage if the pasture CP content was higher. For this reason, partial replacement of corn with citrus pulp for grazing cows should be further studied using pasture with higher CP content. In addition, if the price of barley or citrus pulp is favorable compared with corn, their inclusion in rations should be considered because milk yield did not decline and in fact, efficiency of ECM yield was improved with barley. Milk protein yield declined for cows fed CM, so producers that are paid for milk protein should limit the amount of citrus pulp that replaces corn.

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