Milk Production and Composition, Rumen Fermentation Parameters, and Grazing Behavior of Dairy Cows Supplemented with Different Forms and Amounts of Corn Grain

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ABSTRACT

The objectives were to compare milk production and composition, change in body weight and body condition score, rumen fermentation parameters and grazing patterns by cows when supplemented with different forms and amounts of corn grain. In experiment 1, 36 Holstein cows were supplemented with either 6, 6, 6, or 4 kg/d of dry matter of high moisture corn, coarsely ground corn, finely ground corn, or high moisture corn in two equal daily feedings, respectively. Milk yield (30.3 kg/d), milk protein (2.97%), and milk urea N (14.7 mg/dl) were not different among treatments. Body weight change and body condition score change were similar (23.1 kg and –0.24) for the 10-wk study. During experiment 2, four rumen cannulated cows in midlactation were supplemented with 6 kg/d of dry matter from either coarsely ground corn or high moisture corn in two equal feedings after milking. After the p.m. milking, ruminal pH was measured and rumen fluid samples were collected from cows to determine ammonia N and volatile fatty acids at 0.5, 1, 2, 3, …8 h post-corn feeding during grazing. Ruminal pH values were similar for corn supplements, and, with one exception, were 6.0 or below between 5 and 8 h. Ruminal ammonia-N concentrations reached a maximum at 7 h also. In experiment 3, 40 cows were observed for grazing behavior every 30 min for two consecutive days. Cows grazed an average of 6.4 h/d, 4.1 h in the afternoon and 2.3 h in the morning. Milk yield, milk composition, change in body weight, and body condition were similar regardless of the type or amount of corn supplemented.

(**Key words:** dairy cows, grazing cows, corn supplementation, grazing behavior)

Abbreviation key: CGC = coarsely ground corn, **CSH** = compressed sward height, **FGC** = finely ground corn, **HMC** = high moisture corn, **MUN** = milk urea N, **NFC** = nonfiber carbohydrates.

INTRODUCTION

High quality pastures are usually characterized by high concentrations of CP, which is highly degradable in the rumen (2). This results in transport of large amounts of NH_3-N across the rumen wall that is converted primarily to urea in the liver. When high quality pastures are grazed, the ratio of RDP to nonfiber carbohydrates (**NFC**) is often higher than the optimum suggested by Hoover and Stokes (8). Most rumen microbes depend on carbohydrates as sources of energy (8) that can maximize NH_3-N utilization by rumen microbes. Research conducted at Virginia Tech and (16) Pennsylvania State University (5, 6) suggest that increments of dry corn supplementation has little effect on milk yield when enough herbage is available.

Some workers suggest that the supplemented carbohydrate should have a similar rate and extent of degradation in the rumen to that of CP (19) to maximize N assimilation. However, this has been difficult to accomplish in grazing cows. Typically, grazing cows in the United States are supplemented with concentrates based on dry corn. However, dry corn, the most commonly used energy supplement in the United States, is not as highly degraded in the rumen as is high moisture corn (**HMC**) unless finely ground (13).

Experiment 1 was conducted to measure and compare milk yield, and composition, milk urea N (**MUN**), BW change, and BCS change in grazing cows supplemented with coarsely ground corn (**CGC**), finely ground corn (**FGC**), and two amounts of HMC. The objectives of experiment 2, a parallel experiment, were to measure and compare rumen pH, VFA, and NH_3-N concentrations in cows supplemented with either CGC or HMC. Acidity reduces the rate of fiber digestion in the rumen (7), which in time could result in more N waste.

Patterns of grazing intensity are not understood and may provide opportunities for improved supplemention and management schemes. Therefore, in experiment 3,

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time patterns of grazing in lactating cows were observed and recorded.

MATERIALS AND METHODS

Grazing and Feeding Management

Four paddocks (approximately 2.7 ha each) with swards composed primarily of orchardgrass (*Dactylis glomerata*) with lesser amounts of Kentucky bluegrass (*Poa pratensis*) and white clover (*Trifolium repens*) were grazed by lactating cows in an intensive rotation. A new area was made available daily after the p.m. milking by moving an electrified nylon string across the field. When pasture was not grazed to a desired uniform height, stubble was either clipped or grazed by dry cows. Water was readily available at all times. During the second week of June, paddocks were fertilized with 67 kg of N/ha and 19 kg of K/ha.

Corn was fed twice daily after milking. Cows were on paddocks for 7 h (1500 to 2200 h) and for 6 h (0400 to 1000 h) daily after milking. At 2200 and 1000 h they were brought into a dirt lot prior to milking where orchardgrass hay and a mineral-vitamin premix (as percentage: Ca, 16.0; P, 6.5; mg, 2.2; K, 3.5; Cl, 8.0; Na, 6.4; S, 3.2; $NaHCO_3$, 18.0. As mg/kg: Mn, 1100; Zn, 1325; Fe, 265; Cu, 132; I, 20; Co, 3; Se, 5; F, 650. As 1000 IU/kg: vitamin A, 110.2; vitamin D_3, 44.0; vitamin E, 0.55) were available.

Sward Measurements and Analysis

A minimum of 20 compressed sward heights (**CSH**) were assessed twice per week using a disk meter. The disk weighed 700 g, had a diameter of 50.3 cm, and a hole in the center designed to slide on a steel rod. The disk was dropped down the rod (1.5 m) to settle on the sward. The distance between the ground and resting disk was the CSH. Measurements were made every 10 paces along two diagonal transects across the area allotted prior to grazing.

Pasture DM mass (kg/ha) was estimated based on the method of Frame (3). Twice weekly, a minimum of four samples were collected by clipping a quadrant (0.25 m^2 each) at the height of 5 cm every 20 paces in a diagonal transect across the grazing area. Herbage DM yield was based on the average DM weight (55°C for 48 h) of the samples. Pasture samples were later ground to pass a 1-mm sieve of a Wiley mill (Arthur H. Thomas, Philadelphia, PA), and composited according to field (F1, F2, F3, and F4) and month (May, June, and July). Average pasture composition was calculated for each month. Samples were analyzed for DM, ash (1), CP (1), ADF (4), NDF (21), and macro and micro minerals (1) by the Cumberland Valley Analytical Services Laboratory (Maugansville, MD). The NE_L and NFC were calculated using the following equations:

$$NE_L \text{ (Mcal/kg of DM)} = 1.0876 - 0.0127 \times \text{ADF (20) NFC (\%)} = 100 - (\text{CP} + \text{NDF} + \text{Ash} + \text{ether extract}) \text{ (10)},$$

where nutrients are expressed as a percent of DM.

Experiment 1

Cows and experimental design. Twenty-four primiparous and 12 multiparous Holstein cows averaging 107 DIM initially were used during a 10-wk study beginning on May 13. Cows were supplemented daily either with 6, 6, 6, or 4 kg of DM/d of HMC, CGC, FGC, or HMC, respectively, in two equal feedings. Modest amounts of corn supplementation were chosen to make it more likely differences in corn could be measured. The experimental design was a restricted randomized complete block design, in which cows were blocked according to parity, then stratified according to milk production and DIM, and randomly allotted to four groups.

During a 10-d adaptation period, cows were fed a TMR during half of the day and grazed a predominantly grass pasture during the other half of the day. Initially (wk 0) milk production, BW, and BCS averaged 36.4 kg/d, 510 kg, and 2.88, respectively (Table 1).

Sample collection and analysis. Milk yield was electronically recorded at each milking. Milk was sampled from two consecutive milkings at 2-wk intervals starting on week 0. Individual a.m. and p.m. samples were analyzed for fat, protein, and SNF at the Blue Ridge DHIA Laboratory (Blacksburg, VA) by infrared spectrometry (Multispec Mark I; Foss Food Technology, Eden Prairie, MN). Additional milk samples (a.m. and p.m.) were collected at 2, 6, and 10 wk to determine MUN by the urease method of Weatherburn (23).

The BW and BCS were determined at 0, 5, and 10 wk. Cows were weighed at noon, prior to the p.m. milking. Body condition score (24) was obtained by four independent evaluators.

Corn was ground in a hammer mill at 270 RPM using a 9.7-mm screen for CGC. Percentages retained per sieve size (mm) were: 77.0, 2.0; 11.3, 1.0; 5.5, 0.5; and 3.4, 0.25. The FGC was obtained by grinding it at 540 RPM using a 4.8-mm screen with percentage retained per sieve (mm): 16.4, 2.0; 34.4, 1.0; 25.1, 0.5; and 15.6, 0.25. The HMC was rolled with a gap setting of 0.79 mm using corrugated rollers. The different types of corn were sampled at 1, 5, and 10 wk of the study. These samples were ground to pass a 1-mm sieve using a Cyclotec mill (Tecator 1093, Hoganas, Sweden), and composites of these samples were obtained for analysis.

Table 1. Nutrient composition of mixed pastures[1] during experiment 1.

	Month					
	May		June		July	
Item	Mean	SD	Mean	SD	Mean	SD
DM, %	23.4	0.66	23.6	2.41	19.0	2.79
Nutrients, % of DM						
OM	89.8	0.40	88.7	0.31	88.3	0.29
CP	19.6	1.69	27.4	3.84	23.9	2.56
NE_L, Mcal/kg[2]	1.68	0.04	1.68	0.07	1.62	0.05
NDF	51.6	3.19	50.7	8.05	56.1	3.19
ADF	25.7	1.22	25.5	2.3	27.8	1.70
Hemicellulose	25.9	2.60	25.2	5.62	28.3	3.27
NFC[3]	14.6	1.49	6.6	4.14	4.3	3.91
Ash	10.2	0.40	11.3	0.31	11.7	0.29
Ca	0.50	0.14	0.54	0.15	0.48	0.07
P	0.37	0.01	0.42	0.02	0.38	0.04
Mg	0.22	0.03	0.27	0.03	0.25	0.02
K	3.7	0.07	4.2	0.11	4.6	0.13
Fe, mg/kg	130	27.59	142	18.06	102	27.61
Mn, mg/kg	55.0	12.83	56.0	3.40	49.0	4.97
Zn, mg/kg	31.0	2.18	38.0	2.36	33.0	4.97
Cu, mg/kg	4.5	1.50	5.7	0.47	6.3	1.30

[1]Pastures were predominantly orchardgrass, with lesser amounts of Kentucky bluegrass and white clover. N = 4 samples/mo.

[2]$NE_L = 1.0876 - (0.0127 \times ADF\%)$.

[3]Nonfiber carbohydrates = 100 − (CP% + NDF% + EE% + Ash%). Ether extract (EE) of 4.0% was used based on actual analysis (3.68%) of grass from the same paddocks during a previous year.

Corn was analyzed for N content by Kjeldahl method (1), ADF (4), and NDF (21). The NFC concentrations were calculated in the same way as was pasture analysis. The NE_L values was taken from NRC (12) tables.

Statistical analysis. Data were analyzed using repeated measures, and the general linear models procedure of SAS (18), with a covariate for pretreatment yield. The model used in the experiment was:

$$Y_{ijkl} = \mu + T_i + P_j + \beta_1 X_k + (TP)_{ij} + C\,(TP)_{(ij)\,k} + W_l + (TW)_{il} + \beta_2 (XW)_{hl} + (PW)_{jl} + (TPW)_{ijl} + E_{ijkl}$$

where

Y_{ijkl} = dependent variable (milk yield, composition, and BW variables),
μ = overall population mean,
T_i = effect of treatment i (i = high HMC, CGC, FGC, or low HMC),
P_j = effect of block (parity)j (j = primiparous or multiparous),
X_k = pretreatment value for y,
β_1 = regression of y on x (covariate),
$(TP)_{ij}$ = effect of interaction between treatment i and parity j,
$C\,(TP)_{(ij)\,k}$ = effect of cow k within treatment i and parity j, (error term for T_i, P_j, and $(TP)_{ij}$)
W = effect of week l (l = week 1, 2, 3, …, 10),
$(WT)_{il}$ = effect of interaction between week l and treatment i,
$(XW)_{kl}$ = effect of interaction between week l and covariate k,
$\beta 2$ = regression of weekly y or x (covariate by week),
$(WP)_{jl}$ = effect of interaction between week l and parity j,
$(TPW)_{ijl}$ = effect of interaction between week l, treatment i, and parity j, and
E_{ijkl} = residual error term.

This same statistical model was used to analyze and compare MUN concentrations between treatments; however, no covariate was included.

Experiment 2

Cows and management. Four ruminal cannulated cows (two Holsteins and two Jerseys) in midlactation were supplemented with 6 kg of DM/d from either HMC or CGC, a Jersey and Holstein each, in two equal feedings. Cows were individually supplemented and were allowed an adaptation period of 17 d prior to the beginning of the trial.

Sample collection and analysis. First ruminal samples were collected and rumen pH was measured at 1345 h, 15 min before corn feeding. Sampling and pH measurements were repeated at 0.5, 1, 2, 3, 4, 5, 6, 7, and 8 h after corn supplementation, between 1430 and 2200 h. Ruminal pH was measured in anterior and dorsal sacs of the rumen using a portable pH meter (model 2000, VWR Scientific, Bridgeport, NJ).

Ruminal samples were collected from the anterior and dorsal region of the rumen, strained through six layers of cheesecloth to 150 ml. Aliquots (5 ml) of rumen fluid were preserved with 1 ml of 25% ortho-phosphoric acid for NH_3 N determination with an additional 1 ml of internal standard (7 μmol/ml of isocaproic acid) for VFA analysis, and both stored at –20°C until analyzed. Rumen NH_3 N was determined as described previously (23).

For VFA analysis ruminal fluid was thawed and centrifuged at 5000 × g for 10 min, and particulates were then filtered through a 0.45-μm Metricel filter (Gelman Sciences, Inc., Ann Arbor, MI). A 0.5 μl-aliquot was injected into a chromatograph (Varian Vista 6000, Varian Vista, Palo Alto, CA) with a glass column packed with 10% SP-1200, 1% H_3PO_4 liquid phase on 80/100 Chromabsorb W AW packing (Supelco Inc., Bellefonte, PA). The column temperature was 125°C. Nitrogen was the carrier with a flow rate of 80 ml/min, and hydrogen and air were used as detector gases with flow rates of 40 and 60 ml/min, respectively.

Statistical analysis. Data were analyzed using the general linear models procedure of SAS (18). Least squares means (LSM) and pooled standard error of the means were obtained. The model used for the experiment was:

$$Y_{ijk} = \mu + T_i + C(T)_{(i)j} + H_k + (TH)_{ik} + E_{ijk}$$

where

Y_{ijk} = dependent variable,
μ = overall population mean,
T_i = effect of treatment i (i = HMC or CGC),
$C(T)_{(i)j}$ = effect of cow j in treatment i (j = 1, 2) (error term for T_i),
H_k = effect of time (h) of sampling k (k = 0, 0.5, 1, 2, 3, …, 8),
$(TH)_{ik}$ = effect of interaction between treatment i and time of sampling k, and
E_{ijk} = residual error term.

Experiment 3

Cows and experimental design. Cows used in experiments 1 and 2 (38 Holstein and 2 Jersey) were supplemented as described in experiment 1. Grazing behavior of the 40 cows was observed as a group. The number of cows grazing, lying, or standing was recorded every half hour. To determine whether current milk yield altered grazing behavior, observations were recorded for each of four Holstein cows with the highest (mean = 33 kg/d) and lowest (mean = 21 kg/d) daily milk yields. Cows were allowed to graze a new area of approximately 0.6 ha daily starting after the p.m. milking. Average CSH and DM yield were 13.8 cm and 1450 kg/ha, respectively.

Sunrise and sunset occurred at 0620 and 2036 h, respectively. Maximum and minimum air temperatures averaged 27.5 and 20.5°C, respectively.

Statistical analysis. Data obtained from the individual grazing behavior observations of the eight Holstein cows were analyzed using the general linear models procedure of SAS (18). Least squares means and standard error were obtained. The model used in the experiment was:

$$Y_{ijk} = \mu + P_i + C(P)_{(i)j} + T_k + (PT)_{ik} + E_{ijk}$$

where

Y_{ijk} = dependent variable,
μ = overall population mean,
P_i = effect of milk production i (i = high (33 kg/d) or low (21 kg/d)),
$C(P)_{(i)j}$ = effect of cow j in production group i (j = 1, 2, 3, and 4), (error term for P_i),
T_k = effect of grazing time k (k = morning grazing or afternoon grazing),
$(PT)_{ik}$ = effect of the interaction between milk production i and grazing time k, and
E_{ijk} = residual error term.

RESULTS AND DISCUSSION

Experiment 1

Pasture and corn composition. Average pasture composition is reported for each month of the experiment (Table 1). Pastures contained high concentrations of CP throughout the experiment, with maximum concentrations during the month of June. Nitrogen was applied at the beginning of that month. Highest NDF and ADF contents were observed during July, which was expected, due to warmer, dry weather. The high proportions of hemicellulose reflected the dominance of grass species, predominantly orchardgrass, in the fields. Relatively high energy values equal to good corn silage were calculated for pastures during May and June, but NE_L declined in July. The higher CP percentage of pastures during June, and the higher CP and NDF percentage of pastures during July resulted in

Table 2. Nutrient composition of corn supplements fed in experiment 1.

	Corn supplement[1]		
Item	HMC	FGC	CGC
DM, %	77.2	94.1	94.0
Nutrients, % of DM			
CP	8.0	8.9	9.6
NE_L, Mcal/kg[2]	2.04	1.96	1.84
NDF	16.8	18.9	22.6
ADF	3.6	4.1	4.3
NFC[3]	69.3	66.3	61.9

[1]HMC = High moisture corn, FGC = finely ground corn, CGC = coarsely ground corn.

[2]NE_L from NRC (12).

[3]Nonfiber carbohydrates = 100 − (CP% + NDF% + Ash% + EE%). Ash (1.6%) and 4.3% ether extract (EE) from NRC (12)).

Table 3. Nutrient composition of alfalfa and orchardgrass (Alf-OG) pasture, alfalfa silage, and orchardgrass hay (OG) in experiment 1.

	Alf-OG Pasture[1]			
Item	June	July	Alfalfa silage	OG Hay[2]
DM, %	25.0	25.0	45.6	89.1
Nutrients, % of DM				
OM	87.9	89.4	86.9	90.6
CP	28.8	19.9	20.9	11.9
NE_L, Mcal/kg[3]	1.74	1.68	1.30	1.39
NDF	31.6	44.8	46.8	68.7
ADF	21.7	25.8	38.0	35.7
Hemicellulose	9.9	19.0	8.8	33.0
NFC[4]	23.5	20.7	16.5	6.9
Ether extract	4.0	4.0	2.5	3.1
Ash	12.1	10.6	13.1	9.4
Ca	0.91	0.65	1.26	0.27
P	0.44	0.43	0.37	0.32
Mg	0.28	0.25	0.33	0.11
K	4.33	4.06	3.58	2.79
Fe, mg/kg	126	81	839	89
Mn, mg/kg	84	52	90	163
Zn, mn/kg	46	36	41	39
Cu, mg/kg	11	7	10	19

[1]Alfalfa-orchardgrass was grazed during the last week of June (wk 7) through the third week of July (wk 10) for 3 h each morning.

[2]Average nutrient composition of orchardgrass hay during the study. Ether extract, ash, and macro and micro minerals of OG hay were obtained from NRC (20).

[3]NE_L for Alf-OG pasture and alfalfa silage = 1.044 − (0.0119 × ADF%), NE_L for OG hay = 1.0876 − (0.0127 × ADF%).

[4]Nonfiber carbohydrates = 100 − (CP% + NDF% + Ash% + ether extract%).

lower calculated NFC (6.6 and 4.3%), compared with May (14.6%). Mineral concentrations were within normal ranges for high quality, predominantly grass pastures (11). Consumption of free choice mineral-salt mix was adequate to meet the mineral needs as a group (12).

Nutrient composition of the different types of corn supplemented is shown in Table 2. Neutral detergent fiber was less for HMC relative to FGC or CGC, therefore a greater NE_L for HMC is expected. The NRC (12) shows a constant NDF for these forms of corn, but lists the different NE_L values shown in Table 1.

Forage availability. Compressed sward height averaged 17.3, 13.7, and 15.6 cm for predominantly grass pastures during May, June, and July, respectively. When CSH was regressed against measured herbage DM yields (kg/ha of DM) the equation (Figure 1) was obtained:

$$\text{DM yields} = -295.38 + 122.39 \times \text{CSH} \ (r = 0.73)$$

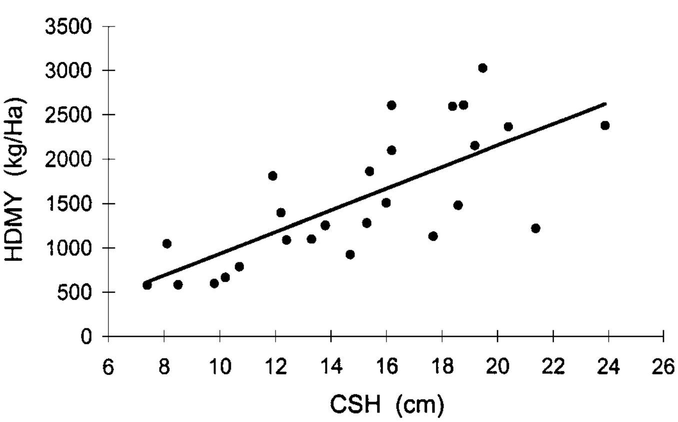

Figure 1. Relationship of herbage DM yield (HDMY) and compressed sward height (CSH) of pasture in Experiment 1. DM yield = 295.38 + 122.39 × CSH (n = 26 paired comparisons, r = 0.73).

The SE for the intercept and slope were 363.1 and 23.3, respectively.

Relatively high DM yield was observed during the second half of May until the beginning of June (wk 5 of the study), with the highest yield observed during week 4. The lowest DM yield was also observed during June (wk 6), when it decreased to 739 kg/ha. After wk 6, DM yield increased to 1300 kg/ha and remained constant until the end of the experiment. The drop in yield after wk 4 was due to unusually low temperatures during the spring and dry weather during the summer, which affected pasture regrowth. As a result, 6.8 kg/d DM of alfalfa silage was added to the diet during wk 5 and 6 of the experiment. At the beginning of wk 7, cows were allowed to graze a mix of alfalfa and orchardgrass for 3 h every morning instead of being fed alfalfa silage. Based on area allotted and DM available, 6.9 kg/d DM per cow of alfalfa and orchardgrass could have been readily consumed for wk 7 through 10. Table 3 shows the chemical composition of the alfalfa-orchardgrass pasture, alfalfa silage, and orchardgrass hay fed during the experiment.

Milk production and composition. Mean weekly milk yield is shown in Figure 2. Milk production curves followed a pattern similar to other studies with cows

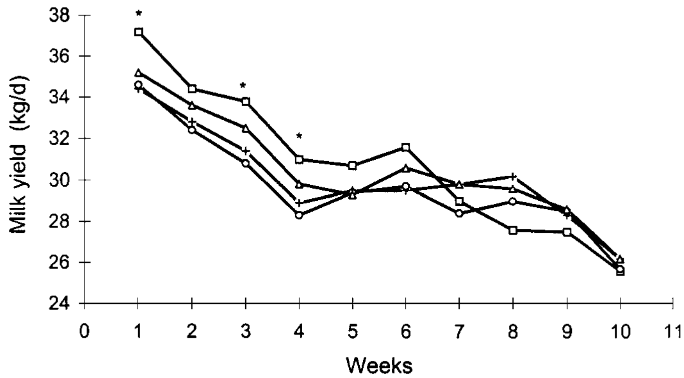

Figure 2. Mean weekly milk yield for grazing Holstein cows (n = 9 cows/treatment) in experiment 1 (SEM = 1.92). Cows were supplemented with 6 kg/d DM of high moisture corn (□), 6 kg/d DM of finely ground corn (○), 6 kg/d DM of coarsely ground corn (+), or 4 kg/d DM of high moisture corn (△). Cows supplemented with 6 kg/d DM of high moisture corn produced more milk ($P < 0.05$) during weeks 1, 3, and 4 (*) compared to the other treatments.

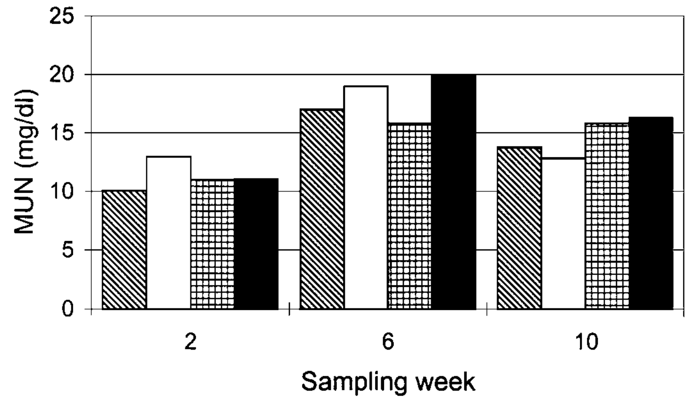

Figure 3. Milk urea N (MUN) concentration during wk 2, 6, and 10 for grazing Holstein cows (n = 9 cows/treatment) in Experiment 1. SEM for wk 2, 1.1; wk 6, 1.3; and wk 10, 1.1 mg/dl. Cows were supplemented with 6 kg/d DM of high moisture corn (diagonal bar), 6 kg/d DM of finely ground corn (open bar), 6 kg/d DM of coarsely ground corn (crosshatched bar), or 4 kg/d DM of high moisture corn (solid bar).

in a similar stage of lactation (5). Milk yield declined rapidly during the first 4 wk of the experiment in all treatments, then plateaued. This rate of production decline with a plateau beyond 4 to 5 wk is typical of our previous studies. This response may be due to limited DM intake from pasture relative to TMR feeding. Least squares means of milk production and composition are shown in Table 4. No significant differences were observed among treatments. However, cows supplemented with high HMC produced more milk during wk 1, 3, and 4 of the experiment (Figure 2). Polan and Wark (15) did not find differences in milk yield between grazing cows supplemented with 4 kg/d DM of either HMC or CGC. Milk fat, protein, and SNF percentages and yields did not differ among treatments.

The MUN concentrations were not different among corn treatments (Table 4). However, the significant time effect and time × treatment interaction can be seen in Figure 3. Milk urea N concentrations were highest during wk 6 of the study (18 mg/dl). This response may have occurred because of higher CP in the pasture caused by N fertilization during wk 5, and alfalfa silage supplementation during wk 6. In a previous study, in which grazing dairy cows were supplemented with HMC or CGC (15), no significant difference was found between treatments in MUN concentrations (17.0 vs. 16.2 mg/dl). These results suggest that NH_3-N utilization by rumen microbes was not improved when cows were supplemented with a more rumen digestible carbohydrate source (HMC vs. FGC vs. CGC), nor when

Table 4. Least-squares means of milk production, composition, and milk urea N (MUN) in grazing Holstein cows supplemented with different forms and amounts of corn in experiment 1.

	Supplement[1]					P^2		
Item	HMCH	FGC	CGC	HMCL	SEM	TRT	TIME	TRT×TIME
Milk yield, kg/d	30.8	29.7	30.1	30.5	1.92	NS	NS	*
3.5% FCM, kg/d	28.3	26.4	28.1	28.1	0.99	NS	NS	*
Fat, %	3.13	2.94	3.23	3.10	0.18	NS	NS	*
Protein, %	2.96	2.99	2.96	2.95	0.08	NS	NS	NS
SNF, %	8.41	8.35	8.32	8.32	0.30	NS	NS	NS
Fat, kg/d	1.02	0.86	0.99	0.94	0.09	NS	**	*
Protein, kg/d	0.89	0.87	0.87	0.88	0.06	NS	NS	NS
SNF, kg/d	2.54	2.44	2.47	2.50	0.16	NS	NS	NS
MUN, mg/dl	13.7	15.0	14.3	15.8	1.65	NS	**	**

[1]HMCH = 6 kg/d DM of high moisture corn, FGC = 6 kg/d DM of finely ground corn, CGC = 6 kg/d DM of coarsely ground corn, HMCL = 4 kg/d DM of high moisture corn.

[2]TRT = Effect of treatment, TIME = effect of time (week), TRT × TIME = effect of interaction between treatment and time.(*$P < 0.05$, **$P < 0.01$).

Table 5. Body weight and BCS in grazing Holstein cows supplemented with different forms and amounts of corn in experiment 1.

	Supplement[1]					
Item	HMCH	FGC	CGC	HMCL	SEM	*P*<
Mean initial BW, kg	538	504	508	525		
BW change, kg						
From wk 0 to 5	26.8[a]	17.2[a]	13.5[a]	2.9[b]	9.5	0.01
From wk 5 to 10	4.0	11.6	3.6	12.9	12.0	NS
From wk 0 to 10	30.8	28.8	17.1	15.8	13.0	NS
Mean initial BCS[2]	2.90	2.85	2.85	2.85		
BCS change						
From wk 0 to 5	–0.35	–0.25	–0.40	–0.35	0.05	NS
From wk 5 to 10	0.15[a]	0.10[a]	0.15[a]	0.00[b]	0.05	0.05
From wk 0 to 10	–0.20	–0.15	–0.25	–0.35	0.07	NS

[a,b]Means within a row with different superscripts differ as indicated.

[1]Supplements: HMCH = 6 kg/d DM of high moisture corn, FGC = 6 kg/d DM of finely ground corn, CGC = 6 kg/d DM of coarsely ground corn, HMCL = 4 kg/d DM of high moisture corn.

[2]1 = thin; 5 = fat.

different amounts of HMC (6 vs. 4 kg/d DM) were included in the diet.

Body condition score and weight change. There were no significant effects of type of supplement on mean average change in BW or BCS (Table 5). The BW change was positive for all groups over the 10-wk study, but BCS change was negative. Body weight reflects changes in body tissue mass and gut fill, while BCS estimates condition only. Cows supplemented with low HMC had lower gain in BW from 0 to 5 wk compared with the other treatments. The BCS declined during 0 to 5 wk for all treatments, but increased during 5 to 10 wk for all treatments except low HMC, which remained constant (Table 5). Although not consistent with weeks, the lower HMC intake seemed to result in less response in BCS and BW change. Over the 10 wk, BCS was less for cows in all treatments than initial BCS; however, mean BCS was never below 2.5. Jones-Endsley et al. (9) found an overall decline of 55 kg in BW and 0.5 units of BCS in grazing cows supplemented with similar amounts of concentrate for 2.5 mo.

Estimation of DMI. Total DMI was estimated during 1, 5, and 10 wk using the equation of Rayburn and Fox (17). Pasture intake was calculated from the difference between estimated total DMI and intake of corn plus hay. During wk 5 and 6, alfalfa silage intake was also subtracted from the total DMI to estimate pasture intake. Intake of orchard grass hay while in the dirt lot, approximately 1 kg/d, was not accounted for in this intake estimation. Average estimated DMI was numerically higher in wk 1 of the study (18.6 kg/d DM), and decreased in wk 5 and 10 (17.4 and 16.6 kg/d DM, respectively). Pasture intake during wk 1 and 10 (12 and 10 kg/d DM, respectively) was similar to those reported in other studies using cows with similar DIM, and milk yield and composition (2, 6). Grain supplementation was slightly higher (7.2 to 7.6 kg/d DM) in the study of Holden et al. (6) compared with the present study. Estimated DMI was approximately 2 to 4 kg/d higher in their study. A similar trend of pasture DMI decrease as the season progressed was observed by Holden and co-workers (6).

The low pasture DMI reported here and elsewhere, combined with the decrease in milk yield observed in the first weeks of this experiment suggests that high producing cows cease grazing before consuming the amount of nutrients required to maintain milk yield. Lower DMI may be the primary factor limiting milk production when cows are grazing high quality pasture compared with when fed a TMR diet. However, other energy costs are involved, such as increased activity and eliminating excess NH_3-N from the body.

Experiment 2

Rumen fermentation patterns. No differences were observed in rumen pH between cows supplemented with 6 kg/d DM of either HMC or CGC (Figure 4). The lowest pH (5.8 to 5.9) for each corn supplement was observed 8 h after corn supplementation. Fluctuations occurred between 5 to 8 h, perhaps influenced by bouts of cud-chewing. Van Vuuren et al. (22) found rumen pH lowest 8 h after grazing lactating cows were supplemented with a high or low starch concentrate. This suggests that the low ruminal pH may have been affected more by forage fermentation rather than starch fermentation. Hoover (7) suggested that ruminal pH in a 5.8 to 6.2 range, even of short duration, may cause a moderate depression in fiber digestion. Rapid rate of

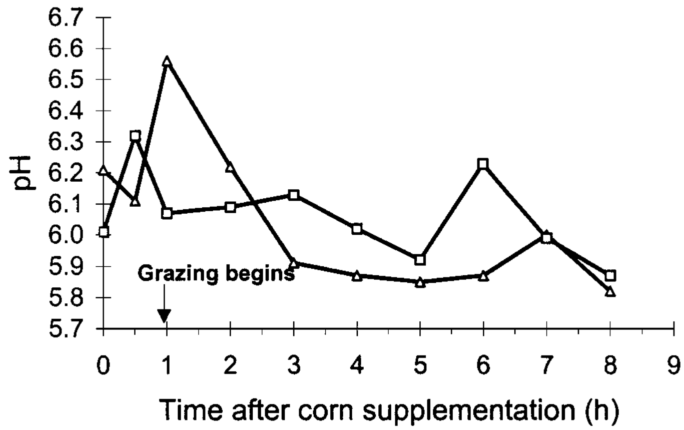

Figure 4. Rumen pH changes over time for grazing cows in experiment 2 (SEM = 0.16). Cows were supplemented with 6 kg/d DM of high moisture corn (△) or 6 kg/d DM of coarsely ground corn (□).

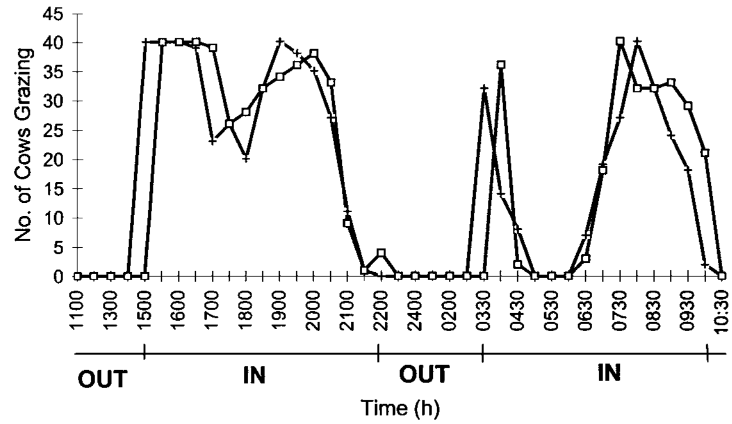

Figure 6. Grazing behavior of 40 lactating dairy cows during two consecutive days in experiment 3. Legend: Day 1 (+), Day 2 (□); the period when cows were not in the field (OUT), the period when cows were in the pasture (IN).

passage may be a greater deterrent to fiber digestion (2) because of less exposure time in the rumen.

No difference was observed in total VFA concentrations (115 m*M*) between treatments. Total VFA tended to increase, reaching maximum levels (135 m*M*) between 4 and 7 h after grazing began. Similar, but slightly higher, responses were observed by Van Vuuren et al. (22). In contrast, lower VFA values (100 to 104 m*M*) have been reported during grazing (9). Molar proportions of VFA followed normal patterns for grazing cows (5). Molar proportions of acetate and propionate averaged about 66 and 19%, respectively, with no differences due to treatment.

Mean ruminal NH_3-N did not differ among treatments. However, the mean NH_3-N concentration was almost 16% lower in cows supplemented with HMC (26.2 mg/dl) compared with CGC (31.0 mg/dl) (Figure 5). The HMC may have been more efficiently fermented by rumen microbes permitting greater incorporation of NH_3-N. In both treatments NH_3-N concentration began to increase abruptly approximately 2 h after the beginning of grazing, i.e., 3 h after corn supplementation (Figure 5) reaching maximum concentrations approximately 6 and 7 h after grazing began. Other workers observed that NH_3-N concentration peaked 8 h after a starchy supplement was fed (22). In our study, corn supplementation may have caused an 2-h lag time after grazing began until NH_3-N accumulated. The readily fermentable starch of corn (coarsely ground corn has some fines) along with the readily digestible portion of forages may have supplied sufficient energy for the microbial population to utilize NH_3-N early in the grazing session.

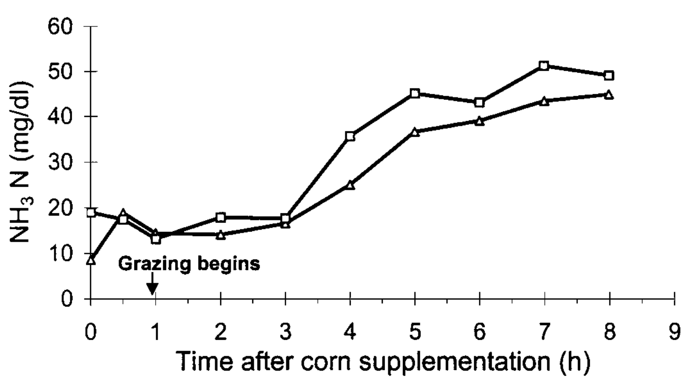

Figure 5. Ruminal NH_3 N concentration over time for grazing cows (n = 2 cows/treatment) in experiment 2 (SEM = 9.2). Cows were supplemented with 6 kg/d of DM of high moisture corn (△) or 6 kg/d of DM of coarsely ground corn (□).

Experiment 3

Grazing behavior. Grazing patterns of the 40 cows as a group were almost identical between days (Figure 6). Due to a delay in the p.m. milking, cows began grazing 30 min later on d 2 compared with d 1.

Four distinctive and nearly identical peaks of grazing activity occurred during both days. The first two peaks occurred in the afternoon: one immediately after the p.m. milking, which lasted approximately 2 h. The second period of intensive grazing activity was observed between 1900 and 2030 h. A third, very short peak (less than 30 min) occurred at night, immediately after the a.m. milking, when cows were taken back to the field. A major peak occurred in the morning, between 0730 and 0900 h. Thus, the most intensive grazing activity occurred in the afternoon, immediately after milking and before sunset.

Table 6. Comparison of grazing behavior between cows producing high and low amounts of milk in experiment 3.

	Milk production[1] (h/d)			
Item	High	Low	SEM	*P*<
Grazing	5.8	6.9	0.24	NS
Lying	5.5	4.2	0.25	*
Standing	1.4	1.7	0.27	NS
Total	12.7	12.8		

[1]High = Averaged 33 kg/d; Low = averaged 21 kg/d.
*$P \leq 0.05$.

A study in the United Kingdom (14) reported two main peaks of grazing activity; one during midmorning and a second peak during late evening. In our study, a new area was allowed for grazing every day, after the p.m. milking. Thus, the intensive grazing activity observed early in the afternoon could have been stimulated by the return to a fresh grazing area.

Total average grazing time for the eight cows observed individually was 6.4 h/d Grazing time did not differ between cows producing high and low amounts of milk (Table 6). However, this does not imply that they consumed similar amounts of DM from pasture, because no accounting was made of intensity of grazing, such as number or size of bites. High producing cows spent more time lying down than did low producing cows (5.5 vs. 4.2 h/d). Observations on the grazing behavior of the eight individual cows agreed with the results from the 40 cows observed as a group. Phillips and Leaver (14) reported a similar grazing time (6.6 h/d) with lactating dairy cows.

Therefore, while in the paddocks, cows spent approximately 50% of the time grazing. Nearly two-thirds of the daily grazing time occurred in the afternoon. This agrees with Phillips and Leaver (24), where the most intense grazing activity occurred after the p.m. milking. The longer grazing activity in the p.m. may have management applications where dairy farmers may want to use grazing as a supplement to a drylot diet.

CONCLUSIONS

Milk yield or composition did not differ when different forms of corn or amounts of HMC were supplemented, even though finer ground or high moisture forms of corn are typically better digested. Also, there was no difference in the rumen fermentation parameters observed between cows supplemented either with HMC or CGC. Numerically, the mean NH_3-N concentration was 16% lower in cows supplemented with HMC, suggesting that efficiency of NH_3-N utilization by the rumen microbes was improved. Cows supplemented with less HMC yielded as much milk as other groups. Apparently, the quality and availability of pasture allowed the cows to compensate for differences in corn supplementation.

With the grazing management used in this study, most of the grazing occurred in the afternoon (64%). However, cows grazed only 50% of the time while in the field. This, combined with the decrease in milk yield observed in the first weeks of experiment 1 suggests that high producing cows cease grazing before consuming the amount of nutrients required to maintain high yields of milk.

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