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Supplemental Dietary Protein for Grazing Dairy Cows: Effect on Pasture Intake and Lactation Performance[1]

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ABSTRACT

One hundred twenty-four cows (92 multiparous and 32 primiparous) were used to evaluate the effect of grain supplements containing high crude protein [(22.8% CP, 5.3% rumen undegradable protein (RUP), dry matter basis], moderate CP (16.6% CP, 6.1% RUP), and moderate CP with supplemental RUP (16.2% CP, 10.8% RUP) on lactation performance of Holstein cows rotationally grazing annual ryegrass-oat pastures. Supplemental protein was provided by solvent extracted soybean meal in the high CP and moderate CP supplements and as a corn gluten meal-blood meal mixture (2.8:1) in the moderate CP, high RUP supplement. Cows were blocked according to previous mature milk equivalent production and calving date (partum group; 0 d in milk or postpartum group; 21 to 65 d in milk) and randomly assigned to dietary treatments. Grain was individually fed, at approximately a 1:3 grain to milk ratio, before a.m. and p.m milkings. The study was replicated during two grazing seasons that averaged 199 d. Cows had ad libitum access to bermudagrass hay while on pasture (dry matter intake = 1.3 kg/d). Protein supplementation had no effect on study long pasture dry matter (12.7 ± 1.0 kg/d) or total dry matter (23.9 ± 1.2 kg/d) consumption. Protein concentration did not affect actual milk yield of either calving group (high CP vs. moderate CP); however, postpartum group cows receiving high CP grain supplements maintained greater milk fat concentrations (3.34 vs. 3.11%), which led to higher fat-corrected milk (FCM) yields than control cows receiving moderate CP grain diets (30.3 vs. 28.9 kg/d). Crude protein concentration in milk of high CP-supplemented, postpartum group cows was also higher than moderate CP cows (3.42 vs. 3.27%). Additional RUP did not increase FCM yield above that generated by moderate CP grain diets for partum (34.3 vs. 32.9 kg/d) or postpartum-group cows (28.9 vs. 28.2 kg/d). Increasing CP concentration of grain supplement did not affect milk yield of Holstein cows grazing immature winter annual pastures. Supplementing additional RUP was without benefit, indicating that in this study energy deprivation may have been the major nutritional constraint for high-producing dairy cows grazing lush pastures.

(**Key words:** dietary protein, dairy cows, milk, pasture)

Abbreviation key: HCP = high CP supplement, **IVTD** = in vitro true digestibility, **MCP** = moderate CP supplement, **MCPRUP** = moderate CP plus RUP supplement, **ME** = mature equivalent, **SP** = soluble protein.

INTRODUCTION

A major constraint limiting the success of pasture-based dairy systems centers on the difficulty associated with accurately determining pasture availability and quality and properly formulating pasture with grain supplements that optimize lactation efficiency (Adkinson, et al., 1993; Parker et al., 1993). A recent survey of 40 dairies in southern Louisiana and Mississippi revealed that more than 75% of the herds received grain supplements containing 18% or more CP (air dry basis), while grazing ryegrass pastures (McCormick, unpublished data). Soybean meal was the primary protein source used in the grain supplements, with fewer than 15% of dairies reporting inclusion of ingredients containing RUP sources in diets of grazing dairy cows. Early lactation cows require diets that contain 18 to 19% CP and 6.5 to 7.2% RUP (DM basis) to optimize milk production (NRC, 1989). Well-managed ryegrass pasture may contain as much as 30% CP, of which as little as 20% may escape the rumen as RUP (McCormick et al., 1999). Consequently, dairy cows that rely on immature ryegrass pastures as their primary forage

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source and are offered copious quantities (10 to 12 kg/d) of 18 to 20% CP grain supplements, often consume complete diets that contain as much as 25% CP (DM basis; McCormick et al., 1999).

The effects of feeding excess CP on lactation performance have been difficult to document because absolute requirements for CP vary with milk yield, protein quality, diet composition, and DMI. Increasing CP from 12 to 18% of diet DM has generally led to incremental improvements in milk yield of confinement-fed, early lactation cows (Kung and Huber, 1983; Zimmerman et al., 1991). Increasing diet CP to 22% or more did not affect milk yield in low fiber, grass-based diets (McCormick et al., 1999); however, increasing CP from 18 to 22% in alfalfa-based diets improved milk yield of Holstein cows during the first 8-wk postpartum (Zimmerman et al., 1991). There is a recognized energy cost associated with overfeeding protein that equates to 0.2 Mcal of NE_L/100 g of excess CP consumed (Twigg and Gils, 1988).

Only recently has information concerning the efficacy of feeding RUP to lactating dairy cattle on pasture become available in the United States. In one study (Hongerholt and Muller, 1998), high RUP grain supplements failed to substantially improve milk yield of early lactation cows grazing orchardgrass pastures. The authors concluded that energy deficiencies in diets limited performance more than specific AA shortfalls. In previous research at this experiment station (McCormick et al., 1999), partial replacement of soybean meal with corn gluten meal and blood meal significantly increased milk yield of early lactation Holstein cows, but did not improve the lactation performance of midlactation cows. However, in that study, annual ryegrass pasture made up less than 40% of the forage consumed, with the remainder as corn silage. The objectives of the present experiment were to evaluate the effect of high versus moderate CP grain supplements and RUP supplementation of moderate CP grain supplements on lactation and reproductive performance of early lactation Holstein cows grazing annual ryegrass-oat pastures. Reproductive data are presented in a companion paper (Chapa et al., 2001).

MATERIALS AND METHODS

Cows and Diet Formulation

One hundred twenty-four Holstein cows (92 multiparous and 32 primiparous) were used in this study that was replicated over two winter annual pasture grazing seasons (October 21, 1995, to May 10, 1996, and October 25, 1996, to May 14, 1997). To be used on the study, multiparous cows needed to possess a mature milk equivalent production (**ME**) of 8600 kg or higher (mean = 10,600 kg), and primiparous cows required an estimate of relative producing ability at least 300 kg above herd average (mean = 425 kg). In addition, eligible cows were required to possess normal, disease-free reproductive tracts before study initiation. Approximately 50% of cows were lactating at study initiation (postpartum group) and the remainder began receiving experimental grain diets at calving (partum group). In yr 1, postpartum cows averaged 40 ± 15 DIM and yielded 36.6 ± 4.9 kg of milk daily, while in yr 2 postpartum cows were 49 ± 19 DIM and yielded 34.5 ± 4.3 kg of milk daily at study initiation. Partum-group cows received experimental diets for a minimum of 120 d and were primarily used to provide sufficient numbers for reproductive evaluation of dietary treatments.

Cows were blocked by previous ME and days postpartum and randomly assigned to the following experimental grain supplements: 1) high CP (**HCP**; 22.8% CP; 5.3% RUP), 2) moderate CP supplement (**MCP**; 16.6% CP; 6.1% RUP), and 3) moderate CP with high RUP supplement (**MCPRUP**; 16.2% CP; 10.8% RUP) (Table 1). All grain supplements were fortified with a mineral supplement so that mineral concentration met or exceeded NRC (1989) recommendations. A small amount of dried molasses was substituted for ground corn to improve palatability of the MCPRUP supplement.

Pasture Management and Feeding

Seven paddocks totaling approximately 40 ha were used during the grazing study. To provide earlier grazing, two paddocks (about 15 ha) were no-till planted on, or about, September 1 of each year with a combination of annual ryegrass (*Lolium multiflorum* Lam.) and oats (*Avena sativa* Lam.) seeded at 34 and 101 kg/ha, respectively. Planting oats allowed cattle to be placed on pastures approximately 3 to 4 wk earlier than possible with pure ryegrass stands, which allowed balancing the number of animals in the partum and postpartum calving groups. The remaining five paddocks were no-till planted to pure ryegrass (45 kg/ha of seed) in mid to late September of each year. Phosphate and potash were applied according to soil test, and 34 kg of N/ha was applied as ammonium nitrate at planting. An additional 227 kg of N/ha was top-dressed on pastures in three applications in late November, January, and March of each year. Grazing was initiated when oat pasture height equaled or exceeded 20 cm (approximately 25 kg of DM/d per cow pasture allowance). Pasture availability, evaluated immediately before grazing, was estimated from forage obtained at six random 0.4-m^2 locations harvested to within 2.5 cm of the ground. Ryegrass-oat pasture grazing (80% oats and 20% ryegrass by visual estimation) began in late Octo-

Table 1. Ingredient and nutrient composition of supplements for cows rotationally grazing ryegrass pastures.

Composition	Grain supplements[1] HCP	MCP	MCPRUP
	% of DM		
Ingredient			
Corn, ground	61.5	80.2	81.7
Soybean meal (54% CP)	34.5	15.8	
Corn gluten meal			7.8
Blood meal			2.5
Molasses, dried			4.0
Minerals and vitamins[2]	4.0	4.0	4.0
Nutrient[3]			
CP	22.8	16.6	16.2
RUP[4]	5.3	6.1	10.8
RDP	17.5	10.5	5.4
ADF	5.1	4.1	2.9
NDF	9.2	9.1	8.9
NFC	57.6	67.4	67.5
NE_L, Mcal/kg[5]	1.90	1.91	1.86
Ca	1.01	1.07	1.28
P	0.63	0.59	0.59
Mg	0.36	0.35	0.39
K	0.80	0.55	0.39
Cu, mg/kg	27.3	26.1	27.7
Zn, mg/kg	75.6	76.3	92.1
Mn, mg/kg	90.6	88.3	103.1
Se, mg/kg	1.1	1.1	1.3

[1] HCP = High CP; MCP = moderate CP; MCPRUP = moderate CP with supplemental RUP.

[2] Mix contained: 27% Ca, 23% NaCl, 6% P, 3% Mg, 0.2% Mn, 0.15% Zn, 0.10% Fe, 0.035% Cu, 0.0006% Co, 0.0023% Se, 2649 IU/kg Vitamin A, 1320 IU/kg Vitamin D_3, and 3 IU/kg Vitamin E.

[3] Nutrient composition of grain supplements are means of weekly samples (n = 56) except RUP, RDP, and minerals which were from monthly composites (n = 12).

[4] Estimated from 12-h in situ protein disappearance of individual ingredients.

[5] Based on NRC (1989) estimates of NE_L for grain supplement ingredients.

ber of each year, whereas grazing pure ryegrass paddocks began in late November or early December of each year. Season-long average stocking rate was approximately 2.5 cows/ha. Cows were rotated between pastures at 12- to 72-h intervals, depending on forage availability. The average rest period for a paddock of ryegrass or ryegrass-oats was approximately 10 d. A relatively constant forage availability was maintained by using "put-and-take" heifers and by diverting approximately 25% of the grazing acreage to silage production in the spring of each year. Cows remained on pastures 24 h/d, except during milking times (0345 and 1445). Large round bales of bermudagrass hay, plain salt, and water were available in all paddocks.

Lactating cows were individually fed experimental grain supplements before a.m. and p.m. milkings. Grain supplement orts were recorded for each cow after each feeding. Nonlactating cows received 4.1 kg of DM from experimental grain supplements daily for 3-wk before calving. During the week following parturition, the amount of experimental grain DM offered was gradually increased to 11.5 kg/d for multiparous cows and 9.8 kg for primiparous cows. At 40-d postpartum, grain offered was increased to a maximum of 13.1 kg of DM daily for cows producing 43.2 kg of FCM or more daily. Cows producing less than 43.2 kg of FCM per day continued to receive the maximum amount of grain by parity (9.8 kg/d for primiparous and 11.5 kg/d for multiparous) until d 100 postpartum, at which time cows were individually fed grain at a 1 to 3 grain to milk ratio (air-dry basis). The amount of grain offered was adjusted according to milk production at 2-wk intervals during the study period.

Pasture intake estimates were obtained by the chromium oxide dilution technique (Holden et al., 1994) applied to a subset of eight cows per diet each year. Intake measurements were conducted during the first 10 d of December, February, and April of each year. Chromium oxide was incorporated into the experimental grain diets by first producing a premix containing 5% chromium oxide carefully blended with finely ground corn. This premix was then incorporated at 1.98% of the experimental grain diet to provide approximately 10 g of Cr per cow per day, the amount varying from 8 to 12 g/d depending on the amount of grain fed. Each batch of experimental grain was sampled in triplicate and later assayed for Cr concentration. Chromium oxide-treated grain supplements were fed before a.m. and p.m. milkings. Grain refusals were recorded for each feeding and used to calculate average daily chromium consumption. On d 6 to 10, fecal samples were collected from each cow before a.m. and p.m. milkings. Fecal samples were dried at 55°C, composited, ground through a 1-mm screen, subsampled, and stored in plastic vials for Cr analysis (Brown et al., 1993). Also, on d 6 to 10, pasture samples were obtained from five random locations within the most recently grazed paddock (n = 25 samples per intake period). Pasture samples were hand-plucked to simulate consumed forage. These pasture samples were dried at 55°C, ground through a 1-mm screen, and stored in plastic vials until subjected to a 30-h in vitro true digestibility test [(**IVTD**) (Goering and Van Soest, 1970)]. Average hay intake was estimated by weighing hay offered and refused during d 6 to 10 of each pasture intake measurement period. Digestibility of concentrates was based on estimates of corn meal digestibility corrected for forage concentration in the diet (Joanning et al., 1981) and hay digestibility was determined from chemical data according to the equation: DM digestibility, % = 87.02 + 0.163 × CP (%) − 0.91 × ADF (%) (Nelson and Montgomery, 1975). Pasture IVTD was used to estimate total

DMI in the initial calculation. A final calculation used diet IVTD rather than pasture IVTD to obtain a more accurate estimate of total DMI (Hongerholt and Muller, 1998). Equations used to estimate pasture intake were:

1) Fecal output (g/d) = g of Cr consumed/ percent fecal chromium/100
2) Initial DMI (g/d) = fecal output (g/d)/[1 − (ryegrass IVTD/100)]
3) Final DMI (g/d) = fecal output (g/d)/[1 − (diet IVTD/100)] where diet IVTD = [(hay intake/initial DMI) × hay IVTD] + [(grain intake/initial DMI) × grain IVTD] + [(initial ryegrass DMI/initial DMI) × ryegrass IVTD]
4) Ryegrass DMI (g/d) = final DMI - (grain DMI + hay DMI).

Cows used for pasture intake measurements were weighed on the last 2 d of each intake period.

Experimental Measures, Sampling, and Analytical Procedures

Milk yield for each cow was recorded daily at a.m. and p.m. milkings. Milk sample composites from a.m. and p.m. milkings were collected at 2-wk intervals and were preserved with 2-bromo-2-nitropropane-1,3-diol and analyzed for CP (N× 6.25), fat, and lactose by infrared analysis (Dairymen, Inc. Laboratory, Franklinton, LA).

Ryegrass pasture samples were collected at 2-wk intervals throughout the grazing period. Paddocks were sampled immediately before grazing in six random locations. Approximately 300 g of fresh ryegrass was obtained from a 0.4-m^2 quadrant by manually cutting each sample site to within 2.5 cm of the ground with a hand-held grass clipper. Sample weights were obtained on fresh forage to obtain DM concentration and an estimate of pasture availability. Samples were dried at 55°C for 72 h, weighed, and ground through a 1-mm screen. Ground samples were stored in plastic vials before being analyzed in the Southeast Research Station Forage Quality Laboratory in Franklinton, LA. Forage quality analyses were conducted by near infrared spectroscopy (Cuomo et al., 1996). Samples identified as outliers from the calibration data set (H > 3.0) were analyzed in the laboratory and wet chemistry values were used. Samples were analyzed for DM, CP (AOAC, 1990), ADF, NDF (Van Soest et al., 1991), in vitro true digestibility (Goering and Van Soest, 1970) and borate-phosphate soluble N (Krishnamoorthy et al., 1982). Nonfiber carbohydrate concentrations were calculated as 100 − (ash, % + NDF, % + CP, % + fat, %). The Dacron bag method was used to estimate RUP of forage and grain supplement ingredients (Stern and Satter, 1984). Pasture samples were composited over locations within pastures and run in triplicate. A single point, 12-h incubation time was selected to represent high DMI and a particulate turnover rate of approximately 8%/h (Petit and Tremblay, 1992). Silage and hay samples were collected at 2-wk intervals and handled as were the ryegrass samples described above. Experimental grains were sampled twice weekly and analyzed by wet chemistry for DM, ADF, NDF, and CP as described above. Concentrations of Ca, K, Mg, Mn, Zn, and Cu in grain supplements were determined by dry ashing, solubilizing in 20% HCl, and analyzing via atomic absorption spectroscopy (Brown et al., 1993). Selenium concentrations were measured by digesting samples in a 10% nitric/4% perchloric acid solution, diluting in deionized water, and analyzing on a Perkin Elmer HGA400 graphite furnace atomic absorption spectrophotometer (Perkin Elmer, Inc., Norwalk, CT; Brown et al., 1993). Chromium in grain supplements and feces was digested as described for Se; however, Cr concentration in the diluted digestate was determined via flame ionization and atomic absorption spectroscopy. Phosphorus was determined by the molybdovanadate colorimetric method (AOAC, 1990).

Statistical Analysis

Daily measures of milk yield and grain consumption were reduced to 14 d means before statistical analysis. Data were analyzed using the general linear model (GLM) procedure of SAS (1989). Terms used in the model to test lactation performance and grain intake were year, parity, calving group (postpartum; 44 ± 17 d vs. 0 d postpartum at study initiation), treatment, and associated interactions. Cow (treatment × year) was used to test treatment effects and residual error was used to test all other main effects and interactions. A second model was used to evaluate lactation performance using repeated measures for time (14-d periods) and the GLM procedure of SAS. Since periods differed within calving group, analyses were conducted within calving groups. Pasture intake data were analyzed with the repeated measures procedure and GLM in a model that included the main effects of year, treatment, and associated interactions. Forage quality data were analyzed with a model that included year, period, and year × period with residual error used to test all effects.

Mean comparisons were conducted with the protected LSD procedure. All treatment mean comparisons involved the preplanned comparisons between grain supplements 1 and 2 (HCP vs. MCP) and supplements 2 and 3 (MCP vs. MCPRUP). Least squares means are presented throughout the manuscript. Unless otherwise stated, differences were considered significant at $P \leq 0.05$, and trends were declared at $0.05 < P < 0.10$.

Table 2. Availability and nutritive value of ryegrass-oat pasture (DM basis).[1]

	Yr 1		Yr 2	
	$\bar{X}$	SE	$\bar{X}$	SE
n	78		84	
Availabale pasture, kg DM/ha	1852	59	2009	62
DM, %[2]	15.6	0.2	14.4	0.2
CP, %[2]	26.8	0.2	23.6	0.2
RUP, %[2,3]	3.4	0.2	3.4	0.2
RUP, % of CP[2,3]	12.5	0.6	14.5	0.7
Soluble protein,[2] %	9.1	0.2	8.0	0.2
Soluble protein, % of CP	33.9	0.4	33.5	0.7
ADF, %[2]	23.6	0.2	27.2	0.3
NDF, %	44.8	0.2	46.8	0.3
IVTD, %[2,4]	88.4	0.3	85.5	0.3

[1] Pasture samples were obtained from six random locations at 2 wk intervals throughout the grazing season. Grazing seasons were from October 28, 1995 to May 10, 1996 in yr 1 and from October 22, 1996 to May 14, 1997 in yr 2.

[2] Year effect ($P < 0.01$).

[3] Estimates obtained from samples composited over pasture locations (n = 14).

[4] IVTD = In vitro true digestibility.

RESULTS

Pasture Availability and Quality

Pasture availability and nutritive value data for yr 1 and 2 are presented in Table 2. Study-long pasture availability averaged 1931 kg/ha, and did not differ with year. However, weather conditions were less favorable for establishment of cool season annuals in yr 1 than in yr 2, as indicated by mean September-October rainfall accumulations of 17.7 and 42.6 cm for yr 1 and 2, respectively. As a consequence, early fall pasture availability was lower in the first year compared with the second year of the study (Figure 1). This trend continued through most of the winter and early spring, but was reversed in late spring when mild temperatures and greater amounts of rainfall in yr 1 promoted regrowth.

In general, ryegrass-oat pasture quality was highest in the fall and early winter and declined as the pasture matured in the spring (Figure 1). Pasture samples collected throughout the 2-year study averaged 25.2% CP, 3.4% RUP, 8.5% soluble protein (**SP**), 25.4% ADF, 45.8% NDF, and 87.0% IVTD (DM basis). The yr-1 pasture samples contained more CP and less RUP, ADF, and NDF than pasture samples collected from yr 2. Also, IVTD was 2.9 percentage units higher for yr-1 than yr-2 samples, with most of the advantage in IVTD for yr 1 samples occurring in the spring (Figure 1).

Pasture Consumption, DMI, and Diet Composition

Daily pasture DM consumption was 12.7 ± 1.0 kg/d per cow, and did not vary with protein supplement (Table 3). Grain supplements were consumed similarly by the test cows averaging 9.9 ± 0.3 kg/d, with total DMI averaging 23.9 ± 0.7 kg/d or 3.8% of BW.

Effects of season and year on estimated DM consumption of cows offered ryegrass pasture are presented in Table 4. Year did not have a substantial influence on supplement intake or total DMI, but cows tended to consume more ryegrass in yr 1 than in yr 2. This trend was due primarily to depressions in pasture DMI measured during the December and April periods (significant period × year interaction; $P < 0.01$). Pasture availability during the December and April intake measurement periods in yr 2 was equal or greater than in yr 1; therefore, period differences in pasture consumption likely were related to lower pasture quality in yr 2 (Figure 1). Grain consumption was similar across periods except for the April intake period, which was 10 to 20% lower than in the fall and winter. Late-season reductions in grain consumption were related to less grain offered because of higher DIM and lower milk production. Reduced grain consumption in late spring did not induce increased pasture consumption by Holstein cows, therefore total DMI tended to decline in late spring.

The estimated nutrient composition of total diets for cows rotationally grazing ryegrass pastures and fed grain supplements differing in CP and RUP are presented in Table 5. Diet composition estimates are based on average forage and grain intake during the intake measurement periods and average nutrient composition of hand-plucked pasture samples (n = 25), hay samples (n = 5), and grain samples (n = 5) collected during each intake measurement period. Total diets contained less than 23% DM. As anticipated, dietary CP concentrations were higher for cows fed the HCP supplement

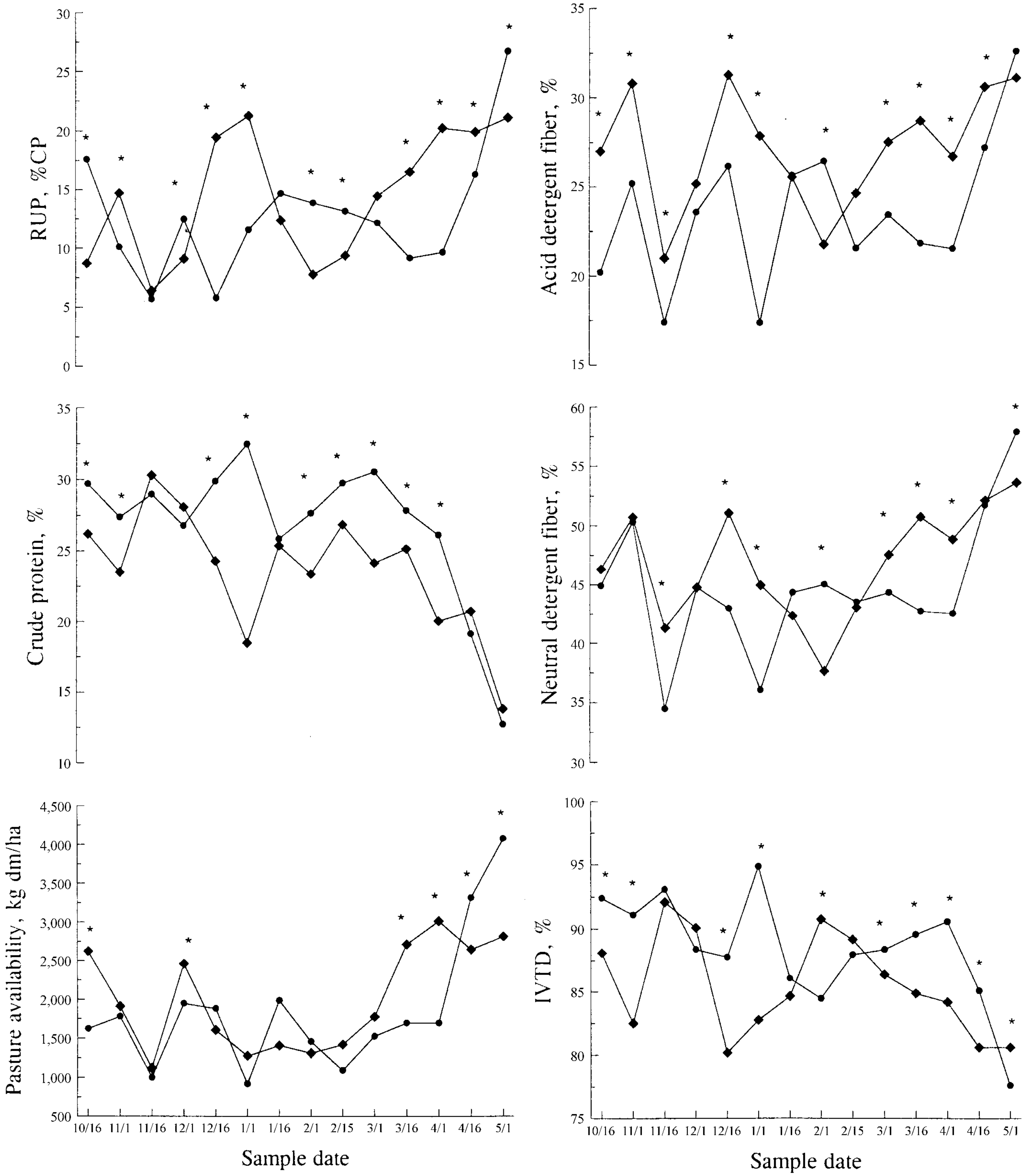

Figure 1. Ryegrass-oat pasture availability and quality (DM basis) for yr 1 (●) and yr 2 (▲). An * indicates a sample date effect ($P < 0.05$). IVTD = In vitro true digestibility.

Table 3. Effects of grain supplements differing in CP and RUP on estimated DMI by cows grazing ryegrass-oat pastures.[1]

	Grain supplements[2]				P[3]	
	HCP	MCP	MCPRUP	SE	S	Yr × S
Cow, no.	16	16	16			
Ryegrass pasture, kg/d	12.5	12.6	13.1	1.0	0.20	0.51
Bermudagrass hay, kg/d	1.3	1.3	1.3			
Grain supplement, kg/d	10.3	9.3	10.1	0.4	0.49	0.50
Total DMI, kg/d	24.1	23.2	24.5	1.2	0.28	0.35
Ryegrass pasture, % of BW	2.0	2.0	2.0	0.2	0.39	0.44
Total DMI, % of BW	3.9	3.6	3.8	0.2	0.41	0.15

[1] Averaged over three sample dates and 2 yr.

[2] HCP = 22.8% CP corn-soybean meal grain supplement, MCP = 16.6% CP corn-soybean meal grain supplement, MCPRUP = 16.2% CP corn-corn gluten meal-blood meal grain supplement.

[3] S = Effect of supplement, Yr × S = effect of interaction between supplement and year.

than either of the two supplements containing moderate concentrations of CP. Substituting corn gluten meal and blood meal for soybean meal increased total diet RUP from 4.6 to 6.5% of DM. Diet ADF and NDF concentrations were 15.2 and 28.3%, respectively, averaged over grain diets. Total diet nonfiber carbohydrates were slightly higher in MCP-supplemented diets compared with HCP diets because of the higher proportion of corn relative to soybean meal in the supplements.

Lactation Responses

HCP verus MCP supplements. Grain supplement intake, milk yield, and milk composition data by year and calving group for cows fed grain supplements containing differing CP and RUP concentrations are presented in Tables 6, 7, and 8. Grain supplement CP concentration did not affect grain DMI across years, calving groups, or parities ($\bar{x} = 10.0$ kg DM/d). A significant protein supplement by calving group interaction was recorded for milk yield in yr 2. In yr 2, partum-group cows offered HCP produced 37.2 kg/d of milk compared with 34.2 kg/d for cows receiving the MCP. However, study-long actual milk yield did not differ with grain CP concentration (Table 6). Also, grain CP concentration did not affect the efficiency of converting grain DMI to FCM ($\bar{x} = 3.20$ kg of FCM/kg of grain DMI).

No differences in FCM yield were detected for partum-group cows receiving HCP or MCP. Milk from postpartum group cows fed HCP contained significantly more milk fat than that from MCP supplemented cows (3.34 vs. 3.11%). As a consequence, FCM yield was significantly higher for postpartum group cows fed HCP grain supplements than for MCP cows (30.3 vs. 28.9 kg/d). Grain supplement concentration effects were not consistent across calving groups (supplement × calving group interaction; $P < 0.05$) with milk from partum-group cows receiving HCP containing less milk protein and milk from postpartum group cows receiving HCP having more protein than control supplemented cows. Feeding HCP elevated milk protein yield of postpartum group cows relative to MCP-fed cows (1.03 vs. 0.94 kg/d).

Table 4. Effect of season and year on estimated DMI of cows on ryegrass-oat pastures.[1]

	Yr 1			Yr 2			Yr		Month		Yr × Month	
	Dec	Feb	Apr	Dec	Feb	Apr	SE	P	SE	P	SE	P
Cows, no.	24	24	24	24	24	24						
Ryegrass pasture, kg/d[2]	14.0	13.4	13.5	10.5^{a}	14.2^{b}	10.6^{a}	0.5	0.15	0.6	0.03	0.3	0.01
Bermudagrass hay, kg/d[3]	1.3	1.5	1.0	1.3	1.4	1.4						
Grain supplement, kg/d	10.1^{a}	10.8^{a}	8.8^{b}	11.0^{a}	9.7^{b}	9.0^{b}	0.3	NS[4]	0.3	0.01	0.4	0.03
Total DMI, kg/d	25.5	25.8	23.3	22.9	25.4	20.9	0.7	NS	0.7	0.01	1.0	NS
Ryegrass pasture, % BW	2.1	2.1	2.1	1.6^{a}	2.2^{b}	1.7^{a}	0.1	0.16	0.1	0.02	0.1	NS
Total DMI, % BW	4.0	4.1	3.7	3.6^{a}	4.0^{b}	3.3^{a}	0.1	NS	0.1	0.01	0.2	NS

[a,b] Within year monthly means with different superscripts differ ($P < 0.05$).

[1] Intake measurements averaged over protein supplements.

[2] Ryegrass pasture intake estimates derived from a subset of eight cows per supplement per year using the Cr dilution technique.

[3] Group average.

[4] $P > 0.20$.

Table 5. Estimated nutrient composition of total diets for cows rotationally grazing ryegrass-oat pastures and fed grain supplements differing in CP and RUP concentration.[1]

	Grain supplements[2]		
Nutrient composition	HCP	MCP	MCPRUP
	% of DM		
DM[3]			
Yr 1	23.2	22.2	23.4
Yr 2	21.9	22.1	21.5
Mean	22.6	22.1	22.5
CP[3]			
Yr 1	26.0	23.8	23.2
Yr 2	25.6	22.7	22.8
Mean	25.8	23.3	23.0
RUP[4]			
Yr 1	4.6 (17.6)	4.5 (19.0)	6.5 (28.2)
Yr 2	4.6 (17.9)	4.7 (20.6)	6.5 (28.7)
Mean	4.6 (21.3)	4.6 (19.8)	6.5 (28.4)
ADF[3]			
Yr 1	14.9	15.3	13.9
Yr 2	15.6	15.5	14.9
Mean	15.3	15.4	14.9
NDF[3]			
Yr 1	28.3	29.3	28.1
Yr 2	27.8	27.7	28.2
Mean	28.1	28.5	28.2
NFC[5]			
Yr 1	34.1	36.5	38.4
Yr 2	34.4	39.1	38.2
Mean	34.3	37.8	38.3
Ash[3]			
Yr 1	8.8	8.8	8.9
Yr 2	9.2	9.1	9.4
Mean	9.0	9.0	9.2

[1] Nutrient composition of total diets determined from estimates of pasture and hay consumption and grain intake (Table 4).

[2] HCP = 22.2% CP corn-soybean meal grain supplement, MCP = 16.6% CP corn-soybean meal grain supplement, and MCPRUP = 16.2% CP corn-corn gluten meal-blood meal grain supplement.

[3] Values based on actual pasture analyses (75 hand-plucked samples per year) and DMI from this trial.

[4] Values based on 12-h in situ protein degradability of pasture samples composited within season (n = 9). Values in parenthesis are RUP concentrations expressed as a percentage of CP.

[5] Nonfiber carbohydrate.

Significant supplement by calving group × parity interactions were recorded for lactation data; therefore, means by parity (primiparous vs. multiparous) are presented separately for postpartum (Table 7) and partum-group cows (Table 8). The FCM yield did not differ with dietary CP concentration for primiparous, postpartum group cows, but multiparous cows receiving HCP produced more ($P < 0.05$) FCM than cows fed MCP (32.4 vs. 29.5 kg/d). Milk fat yield was not affected by grain protein concentration in either parity of postpartum group cows, but multiparous postpartum group cows receiving HCP produced more ($P < 0.05$) milk protein than controls (1.10 vs. 0.96 kg/d). Supplement CP concentration did not affect milk yield or composition of partum-group cows (Table 8).

MCP versus MCPRUP supplements. Averaged across calving groups, cows on the MCP supplement were offered 10.3 kg of DM/d compared with 9.7 kg of DM/d for MCPRUP supplemented cows (Table 6). Grain DM refusals averaged 0.4 kg of DM/d for MCP fed cows and 0.8 kg/d for MCPRUP supplemented cows. The combination of lower grain offered and greater refusals reduced grain DMI of MCPRUP supplemented cows compared with MCP-supplemented cows (9.0 vs. 9.9 kg DM/d).

Substituting corn gluten meal-blood meal for soybean meal had no effect on FCM yield of postpartum group cows, but lowered ($P < 0.05$) milk yield of partum group cows from 34.3 to 32.9 kg/d. Virtually all of the depression in milk yield with RUP supplementation of partum-group cows occurred in yr 1 (significant year × supplement × calving group interaction; $P < 0.05$). Although concentrations of milk components varied between MCP and MCPRUP supplemented cows, total milk fat and protein yields were similar. Conversion of grain DMI to FCM for MCPRUP was superior to MCP in both partum and postpartum calving groups.

Protein source did not influence FCM yield of either primiparous or multiparous postpartum cows (Table 7); however, FCM yield of primiparous cows in the partum group was higher for cows getting the MCPRUP than MCP (27.6 vs. 25.4 kg/d). Multiparous, partum group cows receiving MCPRUP consumed less grain (10.0 vs. 11.3 kg/d) and produced less FCM than MCP (35.1 vs. 37.2 kg/d; Table 8).

DISCUSSION

Ryegrass-oat pasture quality was similar to that previously reported for rotationally grazed annual ryegrass (McCormick et al., 1999) and orchardgrass (Hoffman et al., 1993). Seasonal variations in quality of rotationally grazed cool-season grasses may occur because of plant maturation, fertilization, grazing management, and associated climactic factors. In the present study, yr 1 ryegrass-oat pastures were 15.3% lower in ADF and 11.9% higher in CP than in yr 2. Though other intrinsic animal and environmental factors likely influenced animal performance, average pasture DMI was 1.8 kg/d higher and FCM yield was 2.8 kg/d higher in yr 1 than yr 2.

Estimated pasture DMI, though similar across supplements, was higher than earlier estimates (McCormick et al., 1999) of ryegrass intake determined using the cut-and-carry method (12.7 vs. 10.5 kg/d). Pasture intake estimates in the present study were similar to those previously reported for Holstein cows rotationally grazing orchardgrass pasture and consuming large quantities of grain DM (Hongerholt and Muller, 1998). Total DMI in our study was higher than previously reported (Hongerholt and Muller, 1998) for early lactation cows on pasture (23.9 vs. 20.5 kg/d), but when expressed as percentage of BW, consumption was similar (3.8 vs 3.6%). Forage represented an average of 58.5% of diet DM according to our data; however, this value may be inflated compared with consumption by all study animals since intake estimates were derived from a subset of multiparous cows that were at, or near, peak intake.

As anticipated, dietary CP concentrations were higher for cows fed the HCP supplement than either of the two supplements containing moderate concentrations of CP; however, all diets contained more CP than required for early lactation cows (NRC, 1989). Based on previous estimates of ryegrass pasture intake and

Table 6. Grain supplement intake, milk yield, and milk composition by year and calving group for cows rotationally grazing ryegrass-oat pastures and fed grain supplements containing differing CP and RUP concentrations.

	Partum[1]			Postpartum			Supplement		Calving group	
	HCP	MCP	MCPRUP	HCP	MCP	MCPRUP	SE	*P*	SE	*P*
Cows, no.										
Yr 1	10	10	12	12	9	10				
Yr 2	9	11	12	9	10	10				
Yr 1 and 2	19	21	23	20	20	21				
Grain DM intake, kg/d[3,4]										
Yr 1	11.1	10.1	9.9	9.1	9.2	8.2	0.4	NS[2]	0.3	NS
Yr 2	10.8	10.9	9.8	9.4	9.1	7.8	0.3	NS	0.2	0.02
Yr 1 and 2[3,5]	10.9	10.5	9.9	9.3	9.2	8.0	0.3	NS	0.2	NS
Milk yield, kg/d										
Yr 1[3]	38.8[a]	39.5[a]	36.2[b]	32.0[a]	30.8[ab]	29.8[b]	0.5	0.01	0.4	0.01
Yr 2[3]	37.2[a]	34.2[b]	33.6[b]	30.7[ab]	31.5[a]	29.4[b]	0.4	0.01	0.4	0.01
Yr 1 and 2	38.0[a]	36.8[a]	34.9[b]	31.3[a]	31.2[a]	29.6[b]	0.3	0.01	0.3	0.01
3.5% FCM yield, kg/d										
Yr 1	37.3[a]	37.6[a]	34.7[b]	31.3[a]	29.1[b]	28.5[b]	0.4	0.01	0.3	0.01
Yr 2[3]	33.7[a]	31.0[b]	31.1[b]	29.2	28.8	28.0	0.4	0.01	0.3	0.01
Yr 1 and 2[5,6]	35.5[a]	34.3[a]	32.9[b]	30.3[a]	28.9[b]	28.2[b]	0.3	0.01	0.2	0.01
FCM/Grain DMI, kg/kg										
Yr 1	3.56	3.43	3.62	3.22	3.01	3.26	0.09	NS	0.07	0.01
Yr 2	3.26	3.00	3.28	3.19[ab]	3.04[a]	3.49[b]	0.08	0.01	0.06	0.05
Yr 1 and 2[6]	3.41[ab]	3.21[a]	3.45[b]	3.20[ab]	3.03[a]	3.38[b]	0.06	0.01	0.05	0.03
Milk fat, %										
Yr 1[3]	3.26	3.23	3.30	3.42[a]	3.18[c]	3.30[b]	0.03	0.02	0.03	NS
Yr 2[3]	2.96	2.97	3.08	3.25[a]	3.05[b]	3.23[a]	0.03	0.01	0.02	0.01
Yr 1 and 2[3,5,6]	3.11	3.10	3.19	3.34[a]	3.11[b]	3.27[a]	0.02	0.01	0.02	0.01
Milk fat, kg/d										
Yr 1[3]	1.23[a]	1.23[a]	1.15[b]	1.07[a]	0.92[b]	0.93[b]	0.01	0.01	0.01	0.01
Yr 2	1.01[a]	0.92[b]	0.96[b]	0.96[a]	0.88[b]	0.92[a]	0.01	0.01	0.01	0.03
Yr 1 and 2[4,5,6]	1.12	1.08	1.05	1.01[a]	0.90[b]	0.92[b]	0.01	0.01	0.01	0.01
Milk protein, %										
Yr 1[3]	3.23	3.28	3.29	3.41[a]	3.29[b]	3.42[a]	0.02	0.01	0.01	0.01
Yr 2[3]	3.14[c]	3.25[b]	3.34[a]	3.42[a]	3.25[b]	3.29[b]	0.01	0.01	0.01	0.01
Yr 1 and 2[3,5,6]	3.19[c]	3.26[b]	3.37[a]	3.42[a]	3.27[c]	3.32[b]	0.01	0.01	0.01	0.01
Milk protein, kg/d										
Yr 1[3]	1.20[a]	1.23[a]	1.13[b]	1.06[a]	0.95[b]	0.97[b]	0.01	0.01	0.01	0.01
Yr 2	1.06[a]	1.00[b]	1.03[ab]	0.99[a]	0.93[b]	0.92[b]	0.01	0.01	0.01	0.01
Yr 1 and 2[3,5,6]	1.13	1.11	1.08	1.03[a]	0.94[b]	0.94[b]	0.01	0.01	0.01	0.01

[a,b,c] Values in a row within a common stage of lactation with different superscripts differ ($P < 0.05$).

[1] Partum group cows received supplements from parturition through study conclusion (DIM = 199 at study conclusion). Postpartum group cows received supplements from 44 ± 15 d postpartum to study conclusion (DIM = 243 at study conclusion). HCP = 22.2% CP corn-soybean meal grain supplement, MCP = 16.6% CP corn-soybean meal grain supplement, and MCPRUP = 16.2% CP in corn-corn gluten meal-blood meal grain supplement.

[2] $P > 0.10$.

[3] Calving group by supplement interaction ($P < 0.05$).

[4] Year by supplement interaction ($P < 0.05$).

[5] Year by calving group interaction ($P < 0.05$).

[6] Year effect ($P < 0.05$).

Table 7. Grain supplement intake, milk yield, and milk composition by parity for postpartum group cows grazing ryegrass-oat pastures and fed grain supplements differing in CP and RUP concentrations.[1]

	Primiparous cows				Multiparous cows			
	HCP[2]	MCP	MCPRUP	SE	HCP	MCP	MCPRUP	SE
Cow, no.	7	6	6		15	14	16	
Milk, kg/d[3]	27.8^{a}	31.5^{b}	27.5^{a}	0.5	33.7^{a}	31.5^{b}	30.0^{b}	0.7
3.5% FCM, kg/d[3]	27.3	28.3	26.5	0.4	32.4^{a}	29.5^{b}	28.6^{b}	0.6
Fat								
%	3.40^{a}	2.90^{b}	3.29^{a}	0.06	3.30^{a}	3.19^{b}	3.26^{ab}	0.06
kg/d	0.93^{a}	0.83^{b}	0.88^{ab}	0.02	1.07^{a}	0.94^{b}	0.93^{b}	0.03
Protein								
%	3.39	3.23	3.41	0.02	3.42	3.28	3.34	0.02
kg/d	0.92	0.91	0.90	0.03	1.10^{a}	0.96^{b}	0.95^{b}	0.02
Lactose								
%	4.89	4.97	4.98	0.02	4.80^{a}	4.65^{b}	4.71^{b}	0.03
kg/d	1.33	1.41	1.32	0.03	1.55^{a}	1.38^{b}	1.35^{b}	0.03
Grain DMI, kg/d	8.4	9.6	8.1	0.5	10.1^{a}	9.5^{ab}	8.7^{b}	0.3

[a,b]Values in a row within a common parity with different superscripts differ ($P < 0.05$).

[1]Values are averages of yr 1 and 2.

[2]HCP = 22.8% CP corn-soybean meal grain supplement, MCP = 16.6% CP corn-soybean meal grain supplement, MCPRUP = 16.2% CP corn-corn gluten meal-blood meal grain supplement.

[3]Supplement × parity interaction ($P < 0.05$).

quality (McCormick et al., 1999), we expected diet composition to average about 23.0, 19.0, and 19.0% CP for HCP, MCP, and MCPRUP diets, respectively. Differences in predicted and actual composition appear related to higher CP in the hand-plucked samples compared with samples harvested to 2.5-cm height and to higher than predicted pasture DMI.

For milk production, feeding the HCP grain diet was expected to either increase milk yield when cows were not consuming adequate DM postpartum, increase milk yield when pasture availability limited intake, or decrease milk yield due to a dietary energy loss associated with urea synthesis. Because actual milk yields were similar between the HCP and MCP treatments, sufficient pasture was assumed to be available to maximize pasture consumption. This assumption is supported by the pasture availability data presented in Figure 1, which indicates that availability seldom fell below 1500

Table 8. Grain supplement intake, milk yield, and milk composition by parity for partum group cows grazing ryegrass-oat pastures and fed grain supplements differing in CP and RUP concentrations.[1]

	Primiparous cows				Multiparous cows			
	HCP[2]	MCP	MCPRUP	SE	HCP	MCP	MCPRUP	SE
Cow, no.	3	5	5		14	16	17	
Milk, kg/d	30.8^{a}	27.2^{b}	28.7^{b}	0.9	39.8^{a}	40.0^{a}	37.3^{b}	0.6
3.5% FCM, kg/d	26.8^{ab}	25.4^{a}	27.6^{b}	0.8	37.8^{a}	37.2^{a}	35.1^{b}	0.6
Fat								
%	2.74^{a}	3.09^{b}	3.27^{c}	0.07	3.22	3.10	3.17	0.04
kg/d[3]	0.74^{a}	0.79^{a}	0.91^{b}	0.04	1.23^{a}	1.17^{ab}	1.12^{b}	0.03
Protein								
%	3.00^{a}	3.36^{b}	3.42^{b}	0.04	3.24	3.23	3.27	0.02
kg/d[3]	0.80^{a}	0.85^{a}	0.94^{b}	0.02	1.21^{a}	1.20^{a}	1.14^{b}	0.01
Lactose								
%[3]	4.64^{a}	5.15^{c}	5.00^{b}	0.04	4.86^{a}	4.85^{a}	4.79^{b}	0.03
kg/d[3]	1.25	1.30	1.38	0.04	1.84^{a}	1.81^{a}	1.69^{b}	0.03
Grain DMI, kg/d	9.2	8.5	8.5	0.7	10.8^{ab}	11.3^{a}	10.0^{b}	0.3

[a,b,c]Values in a row within a common parity with different superscripts differ ($P < 0.05$).

[1]Values are averages of yr 1 and 2.

[2]HCP = 22.8% CP corn-soybean meal grain supplement, MCP = 16.6% CP corn-soybean meal grain supplement, MCPRUP = 16.2% CP corn-corn gluten meal-blood meal grain supplement.

[3]Supplement × parity interaction ($P < 0.05$).

kg of DM/ha, the threshold below which availability has been shown to compromise intake (Redmon et al., 1995). The failure of cows fed MCP to produce more milk than cows supplemented with HCP grain suggests that the energy costs needed to detoxify excess CP in the diet of HCP supplemented cows was not sufficiently large to impact milk production. Estimated total diet composition of the HCP-based diet was 2.5 percentage units higher in CP than the MCP diet (Table 5). Based on energy costs of 0.2 Mcal of NE_l/100 g of excess CP, differences in energy required for ammonia detoxification would be expected to increase NE_L requirement approximately 1.07 Mcal/d (Twigg and Gils, 1988), the equivalent energy required to produce 1.44 kg of 3.5% FCM.

Although actual milk yield was not affected by grain supplement CP concentration, percent milk fat was higher in the cows supplemented with HCP (Table 6). Zimmerman et al. (1991) noted that with high CP, low fiber diets milk fat remained high compared with moderate CP, low fiber diets. The authors concluded that AA from soybean meal were important in moderating milk fat depression in low fiber diets. Another contributing factor in our study may have been the higher concentration of nonfiber carbohydrates present in the MCP diet compared with the HCP diet (67.4 vs. 57.6% of DM). High starch diets have been shown to adversely affect fiber digestion (Joanning et al., 1981), which could contribute to lower milk fat concentration.

Supplemental RUP did not consistently improve milk yield of grazing dairy cows in the present experiment. In previous research at this unit (McCormick et al., 1999), cows receiving supplements containing soybean meal, blood meal, and corn gluten meal immediately postpartum through 140 DIM responded with a 11.9% increase in milk yield compared with cows offered grain diets that contained soybean meal as the sole supplemental protein source. However, in the earlier study, ryegrass pasture was estimated to account for about 35% of the forage DMI, with remainder made up of corn silage. As a result, cows in the earlier experiment consumed an average of 1.6 kg of DM/d from the blood meal-corn gluten meal mixture compared with 1.1 kg/d for cows in the present study. An alternative explanation for the failure of early lactation grazing cows to respond to RUP addition may be related to total CP consumption. Data presented in Table 5 indicate that cows receiving the MCP grain consumed 5.4 kg CP/d, which, according to our RUP estimates, provided 1.1 kg of RUP/d, the amount required to produce 40.0 kg of milk containing 3.3% fat and 3.2% protein (NRC, 1989). Thus, based on results from this study, grazing dairy cows would not likely require supplemental RUP, except possibly for short periods when cows were near peak milk. These findings are supported by the grazing study of Hongerholt and Muller (1998), in which early lactation cows did not increase milk yield when fed supplements fortified with a blend of corn gluten meal and animal proteins.

A positive response to RUP was noted in this study for primiparous cows that began receiving additional RUP immediately following calving, suggesting that depressions in DMI postpartum may be greater for primiparous than multiparous cows, thereby increasing their need for RUP. In an earlier study (Hongerholt and Muller, 1998), RUP supplementation did not stimulate milk production for primiparous cows, but cows were an average of 68 DIM when RUP feeding initiated.

CONCLUSIONS

Ryegrass pasture quality and consumption varied with season and year, but DMI did not vary due to protein concentration or source. Increasing CP concentration in the supplement from 16.6 to 22.8% of DM did not affect actual milk yield of early-lactation Holstein cows grazing ryegrass-oat pastures; however, fat concentration in milk of HCP-supplemented cows was elevated in comparison with milk from MCP-supplemented cows. Although ryegrass-oat pastures contained low concentrations of RUP, supplemental RUP in the form of corn gluten meal and blood meal did not enhance overall lactation performance.

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