Lactation Performance of Holstein Cows Fed Fescue, Orchardgrass, or Alfalfa Silage

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ABSTRACT

Perennial grasses are increasingly being used as an integral part of nutrient management plans, but fescue (*Festuca arundinacea* Schreb.) is often overlooked because of perceived intake problems. A 30-d study was conducted to evaluate the lactation performance of cows fed a fescue silage-based total mixed ration (TMR) compared with orchardgrass (*Dactylis glomerata* L.) and alfalfa (*Medicago sativa* L.) silage-based TMR, when forages are harvested at recommended neutral detergent fiber (NDF) levels. Holstein cows (body weight [BW] = 627 ± 66.0 kg, milk yield = 40.9 ± 6.93 kg/d, parity = 2.6 ± 1.44, days in milk = 152 ± 24.5) were randomly assigned to treatment. Statistical design was a randomized complete block with 10 cows per treatment. The 5 treatments consisted of TMR using first-cutting alfalfa, and first- and second-cutting orchardgrass and tall fescue silage. Diets were formulated to provide 0.95% of BW as forage NDF and contained approximately 18% CP and 1.6 mcg/kg. This resulted in diets of about 30% NDF; for a 612-kg cow, approximately 5.8 kg/d of forage NDF was fed. Second-cutting, grass-based TMR had lower intake than alfalfa and first-cutting forage TMR. Cows consuming second-cutting orchardgrass had lower milk production than did cows consuming other forage TMR. Cows fed fescue TMR had higher milk production than those fed orchardgrass. Indigestible residues were higher, and NDF digestibilities were lower, in second-cutting forages vs. first-cutting forages, likely contributing to the differences observed in intake and resulting differences in milk production. Dairy cows consumed the first-cutting fescue TMR readily and performed as well as those on alfalfa or first-cutting, orchardgrass-based TMR in terms of lactation performance, but fescue and orchardgrass rations will require more concentrate in the ration than alfalfa.

(Key words: dry matter intake, grass, NDF digestibility)

Abbreviation key: ADL = acid detergent lignin, NSC = nonstructural carbohydrates.

INTRODUCTION

The agronomic yield potential of tall fescue (*Festuca arundinacea* Schreb.) was >20% higher than orchardgrass (*Dactylis glomerata* L.) in a New York study (Cherney et al., 2002b). In Indiana grass trials from 1994 to 1996, tall fescue yields were 34% higher than orchardgrass (Kuhn and Johnson, 1997). Despite high yield potential, there are lingering concerns about fescue's quality for dairy cattle, in part because of the major problems associated with old endophyte-infected varieties (Baxter et al., 1985; Strahan et al., 1987).

Most studies that fed fescue to dairy cattle in the past compared the feeding of endophyte-free tall fescue to endophyte-infected tall fescue varieties. Little information is available to compare endophyte-free tall fescue forage with other perennial grasses or alfalfa (*Medicago sativa* L.) directly. Casler et al. (1998) observed that orchardgrass was higher in apparent intake than tall fescue for the same level of forage availability in a study evaluating grass species for management-intensive grazing. In that study, animals were allowed to choose between species. It is not clear from these results whether animals would find fescue acceptable if it were the only forage available. In another study, Fisher et al. (1993) compared fescue and orchardgrass silages fed to lactating dairy cows. They concluded that tall fescue silage was comparable to orchardgrass in supporting milk production and superior to orchardgrass in terms of palatability. It should be noted that the tall fescue in this study was lower in NDF and higher in protein than the orchardgrass, probably accounting for its superior performance. In a third study, Johansen and Nordang (1994) compared the feeding value of meadow fescue (*Festuca pratensis* Huds.) and timothy (*Phleum pratense* L.) silage fed to lactating cows. Those authors concluded that the feeding value of fescue and timothy silage was similar. In that study, fescue was harvested at a slightly later morphological stage than timothy. Our objectives were to evaluate intake and lactation performance of cows fed a fescue silage-based TMR com-

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pared with orchardgrass and alfalfa silage-based TMR when forages are harvested at comparable physiological maturities and chemical compositions.

MATERIALS AND METHODS

Forages consisted of first-cutting alfalfa and first- and second-cutting 'Arctic' orchardgrass and 'Select' tall fescue silage. Our goal was to produce alfalfa forage with 40% NDF and grass forage at 50% NDF. Forages were grown and harvested on the Cornell University Dairy Teaching and Research Unit located near Harford, NY. Alfalfa was harvested the first week of June 1999 (first-cutting, late-bud to early-flowering stage); orchardgrass and fescue (first-cutting, early-boot stage) were harvested in late May 1999. Grass fields received 112 kg N/ha applied as urea the first week of May. An additional 112 kg N/ha was applied after the first cutting each year. Alfalfa was fertilized with P and K according to soil test recommendations. Grasses were harvested a second time the first week of August 1999 (early-boot stage). After cutting, forages were field-wilted, chopped, inoculated with silage inoculants (Pioneer 1174 for grass and Pioneer 11H50 for alfalfa, at about 17 mL/mt; Pioneer Hi-Bred International, Inc., Des Moines, IA), and ensiled by treatment in separate plastic bags (Ag-bag International Ltd., Warrenton, OR).

Mertens (1992) suggests that a maximum NDF intake of 1.2% BW/d can be fed without limiting milk yield potential. In our forage studies, we want to maximize forage intake without reducing milk yield. A consistent amount of forage NDF was chosen, 0.95% BW/d, which allows comparisons among forages and generally results in a calculated dietary NDF intake approaching 1.1% when other ingredients are included. Diets were formulated to provide approximately 0.95% of BW as forage NDF (approximately 30% NDF, DM basis). Diets were balanced for NE_L (1.6 to 1.7 Mcal/kg) and CP (17.5 to 18.0%) with high moisture corn grain, soybean meal, and SoyPLUS (West Central Soy, Ralston, IA) and fed as TMR (Table 1). Diets were formulated with Spartan Ration Evaluator/Balancer for Dairy Cattle (1992) for a theoretical 612-kg Holstein cow 120 DIM, producing 36 kg/d of milk (milk fat = 3.5%; milk protein = 3.2%). Dry matter intake was targeted to be 22.8 kg/d; intake of forage NDF was targeted at 5.8 kg/d. Diets met or exceeded NRC requirements (NRC, 1989).

Fifty Holstein cows (BW = 627 ± 66.0 kg, milk yield = 40.9 ± 6.93 kg/d, parity = 2.6 ± 1.44 , DIM = 152 ± 24.5) were used in this study. Cows within parity were randomly assigned to treatment. Statistical design was a randomized complete block with 10 cows per treatment. Cows were housed in individual tie stalls

throughout the experiment and had free access to water throughout the trial. Cows were offered a TMR for ad libitum intake once daily (0700 h) to allow for 10% orts. The TMR offered and orts were recorded daily. The trial was 30 d in duration, and data collection began on d 1. Feed offered and refused was sampled daily. The study had Cornell University Institutional Animal Care and Use Committee approval. All animals were used in compliance with federal, state, and local laws and regulations involving animal care and use, and the study was conducted in such a manner as to avoid unnecessary animal discomfort.

Cows were milked 3 times daily (0800, 1600, and 0000 h). Milk yield was recorded at each milking. Milk was sampled once weekly at all milkings and composited for each cow. Samples were preserved with 2-bromo-2-nitropropane-1, 3 diol. Samples were analyzed for fat, total protein, MUN, lactose, and SCC at the New York DHI milk testing laboratory (Ithaca, NY; infrared analysis: Foss 605B Milko-Scan; Floss Electric, Hillelrod, Denmark). Cows were weighed weekly beginning with the onset of the trial and concluding with the cessation of the trial. Body condition scores (5-point scale where 1 = thin to 5 = fat [Wildman et al., 1982]) were taken on the same day and time as cow weights.

Diet and dietary ingredients were sampled weekly throughout the 30 d of the trial for DM (60°C, 48 h) determination. Diet forage-to-grain ratio was then adjusted as necessary. Daily feed and ort samples were composited by week. These diet and ort samples were analyzed for CP, NDF, ADF, and sulfuric acid detergent lignin (ADL). Crude protein was estimated by Kjeldahl methods for N concentration ($\times 6.25$) with a copper catalyst (984.13; AOAC, 1990). Neutral detergent fiber, ADF, and ADL were analyzed according to Van Soest et al. (1991), including α -amylase and sodium-sulfite for NDF analysis using the ANKOM system (ANKOM Technology, Macedon, NY) for NDF and ADF. At the beginning of the trial, representative samples of silages and TMR were also analyzed by Dairy One (DHI Forage Testing Lab, Ithaca, NY) for DM, CP, ADF, NDF, soluble protein, nonstructural carbohydrates (NSC), and minerals. The NSC was calculated as $NSC = \% \text{ starch} + \% \text{ sugar}$. Starch was determined using a YSI 2700 SELECT Biochemistry Analyzer (YSI Inc., Yellow Springs, OH). Sugar was determined using a water-soluble sugar method (Hall et al., 1999). The NE_L was estimated using the forage NE_L variable discount method of Van Soest and Fox (1992). For these samples, DM was determined by drying at 135°C for 2 h (930.15; AOAC, 1990). Nitrogen was determined by combustion (Leco Instruments, Inc., St. Joseph, MI) (976.06; AOAC, 1990) and multiplied by 6.25 to obtain CP. Neutral detergent fiber, ADF, and sulfuric acid lignin were ana-

Table 1. Ingredient composition of diets (% of DM).

Ingredient	Alfalfa ¹	OG1	OG2	FES1	FES2
Forage	62.1	53.5	51.2	58.9	48.2
Corn grain, high-moisture	34.3	38.2	34.9	32.7	30.8
Soybean meal	0	0	0	0	9.2
SoyPLUS	2.35	5.1	11.6	5.5	9.2
All-Phos Mineral ²	0.75	0.90	0.9	0.75	0.75
TM Salt ³	0.50	0.64	0.60	0.55	0.55
Limestone	0	1.66	0.8	1.60	1.40

¹Alfalfa = alfalfa silage-based TMR, OG1 = first-cutting, orchardgrass silage-based TMR; OG2 = second-cutting, orchardgrass silage-based TMR; FES1 = first-cutting, fescue silage-based TMR; FES2 = second-cutting, fescue silage-based TMR.

²Round House Milling Company, Cortland, NY. Round House Guaranteed analysis per kg: CP from NPN, 56%; Vitamin A, 173,500 USP Units; Vitamin D, 39,689 USP Units; Vitamin E, 703 IU; P, 19.0%; K, 1%; Mg, 3.8%; S, 2.1%; Mn, 0.30%; Zn, 0.30%; Fe, 1.35%; Cu, 0.05%; Co, 0.002%; I, 0.008%; and Se, 0.004%.

³TM Salt = trace mineral salt (Round House Milling Company, Cortland, NY). Guaranteed analysis: S (min) 3.5%, Fe (min) 8.00%, Zn (min) 18%, Mn (min) 15%, Cu (min) 2%, I (min) 0.2%, and Co (min) 0.2%.

lyzed as cited previously. Soluble protein was determined using a sodium-borate sodium phosphate buffer procedure (Licitra et al., 1996). Calcium, P, Mg, K, Na, Fe, Zn, Cu, Mn, Mo, and Co were analyzed using a Thermo Jarell Ash IRIS Advantage Inductively Coupled Plasma Radial Spectrometer (Thermo Jarell Ash, Franklin, MA). Sulfur was determined by combustion using a Leco Model SC-432 (Leco Instruments, Inc.). Chlorine was determined using potentiometric titration with AgNO₃ using a Brinkmann Metrohm 716 Titrino Titration Unit with a silver electrode (Brinkmann Instruments Inc., Westbury, NY). Fermentation analysis of forage silages, pH and titratable acids was performed by Cumberland Valley Analytical Services (Maugansville, MD).

In vitro fiber digestibility and digestion kinetics of TMR, sampled at the study's beginning, were determined according to Cherney et al. (1997), using the rumen buffer described by Marten and Barnes (1980) and using the Daisy II^{200/220} in vitro incubator and the ANKOM^{200/220} fiber analyzer (ANKOM Technology Corp.). The buffer contained urea. Rumen fluid inoculum was obtained from a non-lactating, rumen-fistulated Holstein cow, offered a medium quality orchardgrass hay diet for ad libitum intake. Duplicate samples (0.25g) were incubated for 48 h at 39°C, followed by treating the undigested residue with neutral detergent solution. Incubation times for digestion kinetic determination were 0, 6, 9, 12, 24, 36, 48, 72, and 96 h. Estimates for kinetic parameters of digestion were determined using a direct nonlinear least squares estimating procedure using the Marquardt option of procedure NLIN in SAS (1998). The model for kinetics of digestion was a simple first-order kinetic equation with a discrete lag time (Mertens and Loften, 1980). Data were analyzed using repeated measures analysis models in the PROC MIXED procedure in SAS, version 7.0

software (1998) according to Templeman and Douglass (1999). The following model was used:

$$Y_{ijk} = \mu + \pi_i + \varepsilon_i$$

where

Y_i = the dependent variable,

μ = overall mean,

π_i = forage ($j = 1, 2, 3, 4, 5$), and

ε_i = residual error.

Data for the intake and production trial were also analyzed using repeated measures analysis models in the PROC MIXED procedure in SAS, version 7.0 software (SAS, 1998) according to Templeman and Douglass (1999). The covariance structure with the best fit was AR (1), which is first-order autoregressive; degrees of freedom were calculated using the Satterthwaite method. The statistical design was a continuous design with diet, week, and week $\times$ diet effects (day for milk production and intake). Week (day for intake and milk production) was repeated, and cow was considered random. Average milk production for the 10 d prior to the start of the study was used as a covariate. Significance was $P \leq 0.05$ unless otherwise stated. Interaction effects of cutting and species were evaluated using the Tukey-Kramer procedure for multiple comparisons ($P \leq 0.05$). The following model was used:

$$Y_{ijk} = \mu + \pi_i + \delta_j + \alpha_k + \delta_j \cdot \alpha_k + \beta (X_{ijk} - X_{..}) + \varepsilon_{ijkl}$$

where

Y_{ijk} = dependent variable,

μ = overall mean,

Table 2. Chemical analysis, pH, and titratable acid analysis of forage silages (% of DM, unless otherwise indicated).

Item	Alfalfa ¹	OG1	OG2	FES1	FES2
Acid detergent fiber	34.7	32.3	30.3	30.4	32.7
NDF	40.6	51.3	49.2	45.0	55.1
Acid detergent lignin	5.96	3.01	6.70	1.78	4.16
CP	24.3	24.7	18.1	26.4	16.2
DM, %	39.9	29.0	49.2	21.8	25.7
Soluble CP, % of CP	72	66	58	60	65
NSC ²	23.6	15.2	24.4	20.7	20.1
NE _L , Mcal/kg ³	1.39	1.34	1.34	1.41	1.26
pH	5.2	4.3	4.3	4.3	4.4
Titratable acid, mEq/g	2.9	5.6	4.3	8.3	4.8

¹Alfalfa = alfalfa silage, OG1 = first-cutting orchardgrass silage, OG2 = second-cutting orchardgrass silage, FES1 = first-cutting fescue silage, and FES2 = second-cutting fescue silage.

²NSC = Nonstructural carbohydrate = % starch + % sugar.

³Net energy equation is from the forage NE_L variable discount method of Van Soest and Fox (1992).

π_i = cow ($i = 1, 2, \dots, 10$),
 δ_j = forage ($j = 1, 2, 3, 4, 5$),
 β = regression coefficient of Y on average milk production (X) for 10 d prior to start of trial,
 α_k = time ($k = 1, 2, 3, 4$ for wk or $k = 1, 2, 3, \dots, 30$ for d),
 $\delta_j \cdot \alpha_k$ = interaction term for time and forage, and
 ε_{ijk} = residual error.

RESULTS AND DISCUSSION

Alfalfa silage was lower in NDF, but similar in ADF to grass silages (Table 2). Alfalfa silage ADL was higher than first-cutting grass silage ADL, but similar to second-cutting grass ADL. Crude protein content of first-cutting grass silages was similar, while second-cutting grass silages were lower in CP. Soluble CP of all forages was high (>57%), as might be expected with the CP values of the forages. The low pH of the grass silages indicated that they were well ensiled, including the second-cutting orchardgrass, which had higher DM than would normally be desirable for proper ensiling. Second-cutting silages also had lower titratable acid than first-cutting silages, but higher titratable acid than alfalfa silage (Table 2). Addition of silage inoculants at ensiling might have facilitated the ensiling process and allowed for proper fermentation.

Chemical analyses indicated that TMR (Table 3) were on average 2.1% higher in CP than TMR formulations using individual ingredients. The NDF of consumed TMR was on average, with the exception of second-cutting grasses, 2.4% lower in formulated TMR; second-fescue TMR was on average 1.1% higher in NDF than had been formulated. Rations were initially formulated using silage samples taken from Agbags (cut at regular intervals and resealed). These samples might not have been representative of what animals consumed. In addition,

cows will sort concentrate components of a ration (Jonker et al., 2002), which can lead to differences in composition between consumed and offered TMR. Alfalfa-based TMR was higher in ADF than the grass silage-based TMR ($P < 0.01$; Table 3) because of the higher ADF of the alfalfa silage compared with the grass silages and because of the fact that alfalfa silage made up a greater portion of the TMR than did the grass silages (Table 1). Second-cutting, grass-based TMR were higher in ADF and NDF than first-cutting, grass-based TMR. Alfalfa-based TMR was higher in ADL than grasses, and second-cutting, grass-based TMR were higher in ADL than first-cutting, grass-based TMR. The year was unusually dry after the first cutting, so forage growth of the second-cutting material was delayed and lower yielding than expected. The drought also resulted in forage with a higher lignin content than probably would have occurred during a less stressful period (Van Soest, 1994). The TMR were only analyzed once at the beginning of the trial for soluble CP, NSC, NE_L, and macrominerals. The NSC of the TMR were similar, with the exception that the second-cutting orchardgrass appeared slightly lower than the other TMR. Potassium concentration in the orchardgrass silage TMR was less than NRC (2001) recommendations. In this range (approximately 0.8 to 0.9% of DM), some studies have shown an impact on intake and milk production (Sanchez et al., 1994a,b), and others have not reported an impact of this level of K on intake or milk production (Dennis and Hemken, 1978). Concentrations of other minerals met requirements.

With the exception of milk true protein concentration and BW (data not shown), all time effects were significant (Table 4). Time $\times$ forage interactions also were significant for all variables, with the exception of milk

Table 3. Chemical analysis of TMR consumed (% of DM, unless otherwise indicated).¹

	Diet ²					SED ³
	Alfalfa	OG1	OG2	FES1	FES2	
Acid detergent fiber	18.0 ^a	13.0 ^d	15.9 ^b	14.7 ^c	16.0 ^b	0.56
NDF	27.0 ^a	27.9 ^a	32.3 ^b	28.8 ^a	32.0 ^b	1.00
Acid detergent lignin	3.97 ^a	1.13 ^{cd}	2.26 ^b	1.10 ^d	1.38 ^c	0.12
CP	20.1 ^{ab}	21.5 ^b	18.4 ^a	21.8 ^b	18.9 ^a	0.75
DM	48.9 ^b	42.9 ^{cd}	55.5 ^a	38.5 ^d	46.2 ^{bc}	2.15
Soluble CP, % of CP	61.2	47.2	36.6	59.1	31.6	
NSC ⁴	39.0	37.3	32.3	38.4	40.0	
NE _L , ⁵ Mcal/kg	1.59	1.71	1.72	1.76	1.72	
Ca	0.94	0.87	0.81	0.85	0.81	
P	0.50	0.48	0.46	0.49	0.49	
Mg	0.29	0.27	0.31	0.24	0.30	
K	2.03	0.88	0.81	2.13	1.76	
Na	0.24	0.36	0.35	0.24	0.23	
Cl	0.53	0.55	0.48	0.47	0.44	
S	0.23	0.21	0.23	0.23	0.27	

^{a,b,c,d}Means followed by different superscript within a row differ ($P < 0.05$).

¹TMR values were corrected for ort values.

²Alfalfa = alfalfa silage-based TMR; OG1 = first-cutting, orchardgrass silage-based TMR; OG2 = second-cutting orchardgrass-silage based TMR; FES1 = first-cutting fescue silage-based TMR; and FES2 = second-cutting fescue silage-based TMR.

³Standard error of the difference.

⁴NSC = Nonstructural carbohydrate = % starch + % sugar.

⁵Net energy equation is from the forage NE_L variable discount method of Van Soest and Fox (1992).

lactose concentration and BCS (data not shown). Where meaningful, time and forage $\times$ time interactions are discussed subsequently. The covariate, average milk production for the 10 d prior to the start of the trial, was not significant ($P > 0.05$) for any variable except milk production per day (Table 4).

Table 4. Least square means for intake, digestibility, milk yield, and the composition and yield of milk components.

	Diet ¹					SED ³	$P \leq$			
	Alfalfa	OG1	OG2	FES1	FES2		For	Time	For $\times$ time	Milk 10
DMI, kg/d	25.5 ^a	27.0 ^a	22.3 ^b	26.8 ^a	22.7 ^b	0.85	0.01	0.01	0.01	0.16
DMI, % of BW	4.14 ^a	4.06 ^{ab}	3.62 ^c	4.23 ^a	3.71 ^{bc}	0.20	0.02	0.01	0.01	0.61
NDF intake, kg/d	6.9 ^a	7.4 ^{ab}	7.2 ^{ab}	7.7 ^b	7.5 ^{ab}	0.40	0.31	0.01	0.01	0.67
NDF intake, % of BW	1.12	1.13	1.17	1.21	1.19	0.06	0.42	0.01	0.01	0.53
Forage NDF intake, kg/d	6.5 ^b	7.3 ^a	5.9 ^b	7.2 ^a	6.2 ^b	0.36	0.05	0.01	0.01	0.63
Forage NDF intake, % of BW	1.05 ^{ab}	1.11 ^a	0.96 ^b	1.13 ^a	0.98 ^b	0.06	0.01	0.01	0.01	0.57
Milk, kg/d	40.5 ^a	40.4 ^a	34.4 ^b	40.4 ^a	36.9 ^b	0.59	0.01	0.01	0.01	0.01
3.5% FCM	40.9 ^a	37.7 ^{ab}	34.9 ^b	41.7 ^a	39.2 ^{ab}	3.1	0.20	0.01	0.01	0.50
DM efficiency ⁵	1.57 ^{ab}	1.57 ^{ab}	1.42 ^a	1.68 ^b	1.58 ^{ab}	0.08	0.08	0.01	0.01	0.13
Milk fat, %	3.70	3.41	3.69	3.46	3.61	0.18	0.34	0.05	0.01	0.39
Total milk protein, %	3.06	3.15	3.03	3.04	3.02	0.11	0.81	0.06	0.01	0.66
Milk lactose, %	4.81	4.78	4.80	4.76	4.64	0.11	0.55	0.01	0.78	0.44
Milk urea nitrogen, mg/dL	16.58 ^{ab}	15.34 ^a	19.50 ^b	19.08 ^b	15.32 ^a	1.58	0.02	0.01	0.01	0.29
Yield, kg/d										
Milk fat	1.46	1.31	1.25	1.46	1.40	0.11	0.29	0.01	0.01	0.41
Milk protein	1.21 ^a	1.20 ^a	1.03 ^b	1.28 ^a	1.16 ^{ab}	0.08	0.06	0.02	0.01	0.45
Milk lactose	1.91 ^a	1.83 ^a	1.63 ^b	2.00 ^a	1.79 ^{ab}	0.14	0.10	0.01	0.10	0.82

^{a,b,c,d}Means followed by different superscripts within a row differ ($P < 0.05$).

¹Alfalfa = alfalfa silage-based TMR; OG1 = first-cutting, orchardgrass silage-based TMR; OG2 = second-cutting, orchardgrass silage-based TMR; FES1 = first-cutting fescue silage-based TMR; and FES2 = second-cutting, fescue silage-based TMR.

²Contrast compares effect of alfalfa vs. grass-based TMR (contrast 1), orchardgrass vs. fescue TMR (contrast 2), and first-cutting, grass-based TMR vs. second-cutting, grass-based TMR (contrast 3).

³Standard error of the difference.

⁴Probability that forage (For), time, forage $\times$ time (for $\times$ time) interaction, and the covariate (milk average 10 d prior to start of trial; Milk10) are significant.

⁵DM efficiency = kg milk/kg DMI.

Figure 1. Dry matter intake during the trial as influenced by forage treatment.

Second-cutting grass-based TMR had lower intake than alfalfa and first-cutting forages on a kg/d basis (Table 4). Second-cutting grass-based TMR also had numerically lower intake on a percentage of BW (Table 4) than alfalfa and first-cutting forages, although the difference was not significant between cows fed first-cutting orchardgrass TMR and those fed second-cutting fescue TMR. Although there was day-to-day variation among treatment means (Figure 1), which accounted for time $\times$ forage interactions, intake of second-cutting orchardgrass after the first 3 d was always numerically lower than alfalfa and first-cutting grasses. Dry matter intake was also lower for second-cutting fescue than

alfalfa and first-cutting grasses until 21 d into the trial. The DM value of second-cutting fescue used for ration formulation was changed on d 21 so that the TMR better reflected the correct forage to concentrate ratio. This adjustment resulted in an increase in intake. It is likely that the higher NDF of consumed second-cutting TMR reduced intake of these TMR and reduced their intake in relation to alfalfa and first-cutting silage TMR. Perennial grass forage generally contains more NDF than legume forage, resulting in lower DMI and consequently lower production when fed as the major source of energy (Mertens, 1994). Aston et al. (1994) observed that cows ate more alfalfa silage than perennial ryegrass silage when silage was fed as the sole source of energy and protein, but not when concentrates were included in the diet at 3, 6, 9, or 12 kg of concentrate/d. Cherney et al. (2002a) also observed that DMI were similar between alfalfa and orchardgrass-based TMR, formulated to contain similar levels of energy, protein, and NDF from forage, when ADF of forages were similar. They also observed that cows fed early-cut orchardgrass-based TMR had higher DMI than those fed late-cut orchardgrass (Cherney et al., 2002a). Second-cut forages were not harvested later than first-cut forages in terms of physiological maturity in this study, but second-cut grasses had higher lignin (Table 1), resulting in higher indigestible residue in the second-cut grasses (Table 5). Potentially digestible fiber was higher in first-cutting orchardgrass-based TMR than in second-cut orchardgrass-based TMR (Table 5). Alfalfa had lower digestibility than first-cutting grasses (Table 5), but cows fed alfalfa did not have lower intake or production. Although not measured in this study, alfalfa is

Table 5. Silages and TMR NDF digestion kinetics.

Item	Alfalfa ¹	OG1	OG2	FES1	FES2	SED ²
Silage						
D ₀ , % of DM ³	18.9 ^a	35.2 ^c	27.2 ^b	35.0 ^c	28.7 ^b	1.24
k, /h	0.086 ^a	0.103 ^a	0.085 ^a	0.060 ^a	0.092 ^a	0.0198
lag, h	5.1 ^{ab}	3.7 ^a	5.8 ^{ab}	9.0 ^b	6.1 ^{ab}	1.24
Indigestible residue, % of DM	18.3 ^b	11.5 ^a	24.4 ^c	12.2 ^a	22.8 ^{bc}	1.37
NDF digestibility, % of NDF	48.3 ^a	72.7 ^b	48.3 ^a	68.9 ^b	54.3 ^a	2.59
TMR						
D ₀ , % of DM	16.8 ^{ab}	24.0 ^c	13.0 ^a	18.3 ^b	14.6 ^{ab}	1.23
k, /h	0.100	0.091	0.154	0.073	0.066	0.0298
lag, h	5.9 ^{bc}	5.4 ^b	6.0 ^{bc}	3.8 ^a	6.9 ^{cd}	0.34
Indigestible residue, % of DM	9.1	8.2	11.7	6.3	13.1	2.47
NDF digestibility, % of NDF	58.1 ^a	72.1 ^b	54.2 ^a	76.3 ^b	59.1 ^a	6.66

^{a,b,c,d}Means followed by different superscripts within a row differ ($P < 0.05$).

¹Alfalfa = alfalfa silage-based TMR; OG1 = first-cutting, orchardgrass silage-based TMR; OG2 = second-cutting orchardgrass silage-based TMR; FES1 = first-cutting fescue silage-based TMR; and FES2 = second-cutting, fescue silage-based TMR.

²Standard error of the difference.

³D₀ = Potentially digestible fiber at $t = 0$ h; k = rate of digestion; indigestible residue = indigestible NDF remaining at $t = \infty$ as determined by a first-order kinetic equation with a discrete lag time (Mertens and Lofton, 1980); NDF digestibility = $100 - (\text{NDF remaining at } t = 48 \text{ h} / \text{NDF at } t = 0 \text{ h}) \times 100$.

reported to have higher rates of passage than grasses (Van Soest, 1994), possibly accounting for the differences observed in this study. Cows fed second-cutting TMR were consuming higher NDF-based diets, which undoubtedly affected intake. However, animals fed these second-cutting rations had lower total NDF intake numerically than did cows fed first-cutting rations. Higher forage NDF intake (Table 4) of cows fed first-cutting grass-based TMR over those fed second-cutting grass-based TMR is a result of higher NDF digestibility (Table 5). Cows fed alfalfa-based TMR had intermediate forage NDF intake, a result that fell between forage NDF intake of cows fed first- and second-cutting grass forage (Table 4). With the exception of second-cutting grass TMR, cows ate more forage NDF than the 0.95% of BW as forage NDF that the diets were formulated for (Table 4). Mertens (1992) suggested that most cows should be able to consume 1.1% of their BW/d as NDF, without limiting milk production, which is in close agreement to what cows fed first-cutting grasses and alfalfa in this study consumed. The lower forage NDF consumed by cows fed second-cutting grass TMR suggests that factors other than NDF alone influenced intake; correlation of DMI with NDF was -0.41 ($P \leq 0.01$). Cows fed a diet high in NDF digestibility had higher DMI than those fed a lower digestibility diet (Robinson and McQueen, 1997). Oba and Allen (1999) also reported that enhanced NDF digestibility increased DMI. In addition, Ketelaars and Tolkamp (1992) suggested that higher quality forage increased the rate of passage of indigestible fiber. This would further account for the differences in DMI observed in this study; DMI was correlated ($P \leq 0.01$) with both digestible NDF ($r = 0.36$) and indigestible residue ($r = -0.46$) (correlations were among grasses only). Despite differences in DMI, there were no differences among treatments in BW (632 ± 67.6 kg) and BCS (2.5 ± 0.58).

Daily milk production tended to follow DMI; cows fed second-cutting silage-based TMR had significantly lower milk production than cows on other treatments. (Table 4). Milk production tended to remain relatively stable over the 30-d trial with all cows on all forages, with the exception of cows on second-cutting orchardgrass TMR (Figure 2). The NDF digestibility of second-cutting grasses was lower, and indigestible residue was higher, than that of first-cutting grasses (Table 5). This result was mirrored in the NDF digestibility of the TMR. Lower NDF digestibility of second-cutting grasses likely contributed to their lower intake, as discussed previously, and thus lower milk production. Milk production was correlated ($P \leq 0.01$) with NDF ($r = -0.23$), digestible NDF ($r = 0.18$), and indigestible residue ($r = -0.26$). (Correlations were among grasses only.) Second-cutting orchardgrass-based TMR had lower

Figure 2. Milk production during the trial as influenced by forage treatment.

NSC than the other 4 TMR (Table 3). The inclusion of NSC in the range of 35 to 42% of dietary DM increases energy density and thus milk production (Lykos et al., 1997). The low NSC, in addition to high indigestible residue, probably resulted in lower milk production of cows fed second-cutting orchardgrass. Second-cutting fescue was higher in NDF, but lower in lignin, than second-cutting orchardgrass (Table 2). This resulted in a higher forage-to-concentrate ratio for the second-cutting orchardgrass TMR (Table 1). Greater levels of concentrate would increase milk production (Weiss and Shockey, 1991).

The 3.5% FCM production was closer among treatments than uncorrected milk production, although cows fed second-cutting orchardgrass TMR still had lower FCM than cows fed alfalfa or first-cutting fescue TMR (Table 4). This was because even though differences in milk fat percentage were not significantly different, cows fed first-cutting forages had numerically lower milk fat percentage than those fed second-cutting grasses. Correlations of FCM with NDF, digestible NDF, and indigestible residue were lower than correlations among grasses of milk and DMI with these variables: $r = -0.21$ ($P \leq 0.01$), $r = 0.10$ ($P = 0.15$), and $r = -0.18$ ($P \leq 0.01$), respectively, for the correlation of FCM with NDF, digestible NDF, and indigestible residue. Total true milk protein and milk lactose percentage also did not vary among treatments. Phipps et al. (1987) reported that an improvement in perennial ryegrass silage quality did not improve milk fat concentration, but significantly increased milk protein concentration, and Cherney et al. (2002a) noted that improved orchardgrass quality improved milk protein. Weiss and Shockey (1991) and Orozco-Hernandez et al. (1997) did

not report differences in milk composition when different silage types (grass or alfalfa) were fed. The improvement in quality in the present study was probably insufficient to allow for significant differences caused by treatment. Coupled with differences in milk yield, however, the trend toward difference in milk true protein did result in higher milk protein yields for cows fed first-cutting orchardgrass-based TMR vs. those fed second-cutting orchardgrass-based TMR (Table 4). Cows fed alfalfa-based TMR had similar milk protein yields compared with cows fed first-cutting grass-based TMR. Most of the differences observed could be attributed to differences in milk production.

Cows fed second-cutting orchardgrass TMR and first-cutting fescue TMR had highest MUN, those cows fed first-cutting orchardgrass and second-cutting fescue had lowest MUN, and those cows fed alfalfa TMR had intermediate MUN (Table 4). Because of lower ration CP, lower ration soluble CP, and higher NSC (Table 2), lower MUN from cows fed second-cutting orchardgrass TMR would have been expected in comparison with those fed first-cutting orchardgrass TMR, as it was for cows fed fescue-based TMR. Reasons for this discrepancy are not apparent.

Cows fed alfalfa had a DM efficiency that was not different from those fed the grass silages (Table 4). Cows fed fescue TMR had numerically higher DM efficiencies than those fed orchardgrass-based TMR. Higher quality forage will improve DM efficiency.

CONCLUSIONS

Lactation performance of dairy cows fed fescue silage-based TMR compared favorably with orchardgrass and alfalfa silage-based TMR when forages were harvested at recommended fiber levels. Cows fed first-cutting, late-bud to early-flowering stage alfalfa-based TMR had similar intakes and milk production as those fed grass silages, particularly those fed first-cutting grass-based TMR. Cows consuming second-cutting grass-based TMR had lower intake and milk production than did cows consuming corresponding first-cutting grass-based TMR. Differences in DMI and subsequent milk production could be attributed to differences in fiber digestibility and indigestible residue, resulting from lignin differences, as well as to differences in NSC and to higher NDF of second-cut grass TMR. This study demonstrated that dairy cows would consume fescue TMR readily and that CP levels compared favorably with well-managed alfalfa and orchardgrass. Cows fed fescue would perform as well as those cows fed alfalfa-based TMR or orchardgrass-based TMR, provided that the forage is of adequate chemical composition. Both orchardgrass and fescue-based silage TMR would re-

quire a higher concentrate proportion to yield similar results as alfalfa. Because all diets contained excess CP, it is impossible to discuss the efficiency of N utilization of these forage sources. Further work needs to be done with these forages comparing N utilization.

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