Performance of Lactating Dairy Cows Fed Alfalfa Silage or Perennial Ryegrass Silage

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ABSTRACT

The nutrient contents of perennial ryegrass (*Lolium perenne* L.) and alfalfa (*Medicago sativa* L.) are reasonably similar. Despite similarities, the lactation performance of dairy cows fed perennial ryegrass has not been compared with the lactation performance of dairy cows fed alfalfa. The present study was implemented to compare the performance of lactating cows fed alfalfa or perennial ryegrass silage. Alfalfa and perennial ryegrass were harvested at late bud and boot stages of maturity, respectively, and ensiled in separate 4.9- × 18.3-m concrete silos. The experimental silages were supplemented with a concentrate mix at 31.1% of dietary dry matter and fed to 18 multiparous Holstein cows in early lactation in a crossover experimental design with 28-d periods. Digestibility and rate of passage of experimental diets were also measured using rare earth markers.

The perennial ryegrass contained 3.0 percentage units more neutral detergent fiber than did alfalfa, but in vitro digestibility of neutral detergent fiber was 8.8 percentage units higher for perennial ryegrass. In vitro digestibility of dry matter was also higher for perennial ryegrass.

Cows fed alfalfa silage produced more milk (31.8 kg/d) than did cows fed perennial ryegrass silage (30.2 kg/d). Cows fed perennial ryegrass silage ate less feed (2.2 kg/d) than did cows fed alfalfa. Because dry matter intake was lower, diet digestibilities were higher, and rate of passage was slower, for cows consuming perennial ryegrass. Based on laboratory evaluations, perennial ryegrass silage has high nutritional quality, but performance of lactating cows indicated that the forage was suboptimal for supporting high milk production when compared with alfalfa. The perennial ryegrass silage was suboptimal because it did not stimulate high amounts of dry matter intake in lactating cows.

(**Key words**: perennial ryegrass, alfalfa, lactation)

Abbreviation key: **AS** = alfalfa silage, **PRS** = perennial ryegrass silage.

INTRODUCTION

In the midwestern United States, dairy producers traditionally harvest perennial forages three to four times per year. Under this management system, perennial legumes are preferred over perennial grasses because perennial grasses contain more NDF, which is negatively correlated with the DMI of ruminants (13). Perennial grasses, however, differ greatly in NDF content. Perennial ryegrass has been demonstrated (3, 8) to have markedly lower NDF contents than do other cool season perennial grasses. In an extensive study of the nutritional characteristics of perennial forage species, Hoffman et al. (8) found that perennial ryegrass contained 7 to 8 percentage units less NDF than did timothy (*Phleum pratense* L.), bromegrass (*Bromus inermis* Leyss), orchardgrass (*Dactylis glomerata* L.), or quackgrass [*Elytrigia repens* (L.) Nevski] at any of three stages of maturity. Perennial ryegrass also contained less lignin, and the NDF in perennial ryegrass was more ruminally degradable than was that of other cool season perennial grasses.

Despite evidence that suggests the high nutritional quality of perennial ryegrass, the performance of animals fed this forage is often lower than that of animals fed legumes. Thomas et al. (22) fed lactating dairy cows red clover silage or perennial ryegrass silages (**PRS**) of equal energy contents but observed lower DMI and milk production when cows were fed PRS. Reduced DMI and growth were observed by Rattray and Joyce (18) when sheep were fed perennial ryegrass compared with the feed intake and growth of sheep fed an isocaloric white clover. These data (18, 22) suggest that the high nutritional quality of perennial ryegrass observed in some studies (3, 8) may be poorly correlated with animal performance. The intent of the present study was to investigate nutritional paradoxes of perennial ryegrass when fed to high producing dairy cows in early lactation.

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MATERIALS AND METHODS

Forage Harvest

Late summer growth herbage from two 4.0-ha fields containing either alfalfa (*Medicago sativa* L.) or perennial ryegrass (*Lolium perenne* L.) was cut and swathed on August 24, 1994. The field containing alfalfa was direct seeded using chemical weed control in spring 1992, and, at harvest, alfalfa was at stage 5 (late bud) of development as described by Kalu and Fick (11). The field containing alfalfa had high soil P and K concentrations at 72 and 175 ppm, respectively, and no fertilizer was applied between planting and harvest on August 24, 1994. The field containing perennial ryegrass was planted in spring 1993 and was underseeded with alfalfa. Because of extremely wet and cool climatic conditions, perennial ryegrass flourished, and alfalfa survival was poor. As a result, the field containing perennial ryegrass was managed for grass production. In October 1993 and again in July 1994, 79 kg of N/ha were applied to the field. At harvest, August 24, 1994, perennial ryegrass was at stage 19 (boot) of development as described by Simon and Park (21), and the field containing perennial ryegrass also contained some alfalfa at stage 5 (11). To assess the possible confounding effects of alfalfa in perennial ryegrass on a lactation trial, the following assessment methods were used. Experimental forages were wilted for 30 h, chopped with a forage harvestor to a theoretical length of cut of 1 cm, and conserved as low moisture silage in separate 4.9- × 18.3-m concrete stave silos. Prior to ensiling, each load of forage from alfalfa (n = 15) and perennial ryegrass (n = 18) was sampled, immediately analyzed for DM by oven-drying for 48 h at 55°C, and ground through a UDY mill (1-mm screen; UDY Corp., Boulder, CO). The percentage of grass in alfalfa and perennial ryegrass was determined by near infrared spectroscopy (NIR Systems, Silver Spring, MD). The calibration equation used to predict the percentage of grass was developed from agronomic experiments conducted at the Marshfield Agricultural Research Station, where botanical separations of legume and grass species were made. The R^2 and standard error of calibration were 0.99 and 2.8%, respectively. The percentage of grass in alfalfa and perennial ryegrass was estimated to be 7.0 ± 1.0% and 82.0 ± 2.5%, respectively. Based on the pretrial assessment, some confounding effects caused by forage species variation in alfalfa and perennial ryegrass would be present in a lactation trial. However, the confounding effects created by forage species variation in alfalfa and perennial ryegrass are relatively small, and we found no literature that suggested the presence of a synergism that would diminish the validity of the data.

Lactation Trial

Eighteen multiparous Holstein cows in early lactation (61 ± 13 d) were ranked according to days in milk and alternately assigned to one of two dietary treatments. Treatment diets consisted of alfalfa silage (**AS**) or PRS supplemented with a concentrate mix at 31.1% of dietary DM. Treatments were administered in a crossover design consisting of two 28-d periods. Cows were allowed to adapt to treatment diets for 21 d, and data were collected during the final 7 d of each period.

Treatment diets were mixed and fed as a TMR at 0800 h. Amount of the TMR offered was recorded, and treatment diets were sampled daily for the last 7 d of each period. Orts were weighed, recorded, and sampled according to the same procedures followed for the treatment diets. Silages were sampled three times per week throughout the experiment. Silage samples were divided, and an undried subsample was frozen for later analysis of organic acids, pH, yeast, and mold.

The remaining silage subsample was immediately analyzed for DM by oven-drying for 48 h at 55°C. Dry matter contents of the treatment diet and ort samples were determined by identical methods. Silage, treatment diet, and ort samples were ground through a Wiley mill (1-mm screen; Arthur H. Thomas, Philadelphia, PA) and retained for chemical analysis. All samples were analyzed for CP and absolute DM according to AOAC (1) procedures. Acid detergent fiber and NDF were determined nonsequentially according to the procedures of Goering and Van Soest (6) with modifications by Mertens (12).

Silage pH was determined, and extracts for organic acid determination were prepared, according to the procedures of Hoffman et al. (9). Organic acids were quantified by ion exclusion chromatography (5) using a Dionex QIC ion chromatograph (Dionex, Sunnyvale, CA). Yeast and mold counts were determined using the spread plate enumeration technique (19), except potato dextrose agar was used instead of Sabovraud maltose agar. Calcium and P were determined by atomic absorption spectroscopy and colorimetric methods, respectively (Coleman Instruments, Inc., Maywood, IL).

In vitro NDF digestion kinetics and 48-h in vitro DM digestibility of the silages were evaluated according to the procedures of Goering and Van Soest (6). In vitro analyses were conducted on a composite of the weekly forage samples for each period. Samples

were incubated in duplicate for 0, 4, 8, 12, 24, 48, and 72 h. Ruminal fluid was collected from a dry cow fitted with a ruminal cannula and fed a treatment diet containing 88.0% alfalfa and grass silage, 8.0% shelled corn, 2.5% wheat middlings, 1.0% of a mineral supplement, and 0.5% NaCl, and vitamins of ration DM.

Digestion kinetics of NDF were calculated using the nonlinear regression procedures of SAS (20) and were fitted to the model of Mertens and Loften (14). Ruminal availability of NDF was estimated using the equation: digestible fraction $(B)(k_d/k_d + k_p)$, where k_d = degradation rate and k_p = ruminal passage rate (0.06/h).

Cows were housed in a free-stall barn equipped with Calan gates (American Calan, Inc., Northwood, NH) and milked twice daily at 0230 and 1430 h. Milk weights were recorded daily, and milk was sampled twice daily on d 23, 25, and 27 of each period. Milk fat and protein were determined on individual milk samples by automated techniques (Central Wisconsin DHIA, Colby, WI).

Digestion Trial

A digestion trial using 10 cows assigned to the lactation trial was conducted simultaneously with the lactation trial. Nutrient digestibility and rate of passage of diets used in the lactation trial were evaluated during collection periods using 5 cows fed AS and 5 cows fed PRS. Digestibility and passage measurements were taken using the same cows each period. Nutrient digestibilities in the total tract were determined by feeding 0.45 kg/d of a concentrate marked with 485 ppm of La from d 18 to 28 of each period. The marked concentrate was prepared according to the procedures of Hartnell and Satter (7) and fed separately from the TMR at 0730 h to assure complete consumption. Ruminal passage rates were estimated by pulse-dosing cows with Cr-mordanted fiber on d 21 of each period. Chromium-mordanted fiber was prepared according to the procedures of Combs (4) and contained 80,000 ppm of Cr. A 12.5-g dose of Cr-mordanted fiber was mixed with the concentrate marked with LA that was fed on d 21 of each period and fed via procedures described previously.

Fecal grab samples were taken at 6, 10, 14, 18, 22, 26, 30, 36, 42, 50, 58, 70, 82, and 96 h postdosing. Fecal samples were dried in a 55°C forced-air oven and were analyzed for CP, ADF, and NDF according to the procedures previously described for the lactation diet and ort samples. In addition, feed, ort, and fecal samples were assayed for OM by ashing at 500°C for 2 h.

Chromium concentrations of all fecal samples and La concentration of period composites of individual dry, ground fecal samples for each cow were analyzed by direct current plasma emission spectroscopy (4). Rates of ruminal passage were calculated as the slope of the linear regression of the descending portion of the natural log of Cr concentration in the feces with time.

Statistics

Lactation and digestion trial data were analyzed using the general linear models procedures of SAS (20) with the models

$$\gamma = \mu + S_i + C_j(S)_i + P_k + T_l + e_{ijkl}$$

where

γ = dependent variable,
μ = overall mean of the population,
S_i = mean effect of the crossover sequence i,
$C_j(S)_i$ = mean effect of cow j nested within sequence i,
P_k = mean effect of period k,
T_l = mean effect of treatment l, and
e_{ijkl} = unexplained residual element assumed to be independent and identically distributed.

Differences in silage nutrient parameters, fermentation characteristics, and in vitro digestion kinetics were also tested (dependent variable = treatment + error).

RESULTS AND DISCUSSION

Silage Quality

Nutrient composition, fermentation characteristics, and in vitro NDF digestion kinetics of experimental silages are presented in Table 1. The AS contained more CP and Ca and less NDF than did PRS. Differences in CP, Ca, and NDF between AS and PRS are consistent with known nutrient differences relevant to stage of maturity at harvest between alfalfa and perennial ryegrass (8).

Because silage fermentation characteristics and microbial populations at feedout can affect animal performance (16), silage fermentation characteristics and microbial populations were evaluated. The pH values at feedout averaged 5.9 and 5.8 for AS and PRS, respectively. These pH values are normal for legume and grass silages ensiled at approximately

50% moisture (16). No differences in organic acid contents between AS and PRS were detected at feedout, except that PRS had a higher ($P < 0.05$) lactate content. Despite generally low organic acid contents, mold ($<10^4$ cfu/g) and yeast ($<10^5$ cfu/g) concentrations were very low at feedout, which is supportive of our empirical observations that both silages were aerobically stable. The PRS contained more ($P < 0.01$) digestible NDF and less ($P < 0.01$) undigestible NDF than did AS. Rate of NDF digestion and lag time of NDF digestion between AS and PRS was not different. A greater digestible NDF fraction combined with a similar NDF digestion rate of PRS as compared with the NDF of AS resulted in a greater ($P < 0.01$) potentially digestible NDF fraction for PRS. Further, in vitro DM digestion (48 h) was higher ($P < 0.01$) for PRS than for AS. Differences observed in NDF and DM digestion between AS and PRS in this study are identical to differences observed in a previous in situ study conducted in our laboratory (8). Previously observed differences (8) were the foundation for the hypothesis of this experiment, which stated that, although perennial ryegrass contains slightly more NDF (maturity relevant) than alfalfa, NDF and DM of perennial ryegrass may be more digestible than the NDF and DM of alfalfa. Because of these characteristics, perennial ryegrass may support similar milk production when compared with alfalfa (maturity relevant). Nutrient composition, fermentation characteristics, and in vitro digestion data suggest that alfalfa and perennial ryegrass were harvested at appropriate maturities and properly stored to investigate this hypothesis.

Lactation Study

The ingredient and chemical composition of the treatment diets is presented in Table 2. Diets were isonitrogenous, and both CP and RUP were supplied at concentrations to support the production of approximately 40 kg/d of 4% FCM by a 590-kg cow (17). Diets contained energy concentrations that were lower than NRC (17) requirements for the previously mentioned milk production. Energy concentrations of

TABLE 1. Nutrient composition, fermentation characteristics, and in vitro digestion of experimental silages.

Item	Experimental forage[1]		SE	Effect
	AS	PRS		
Nutrient				
DM, %	54.2	50.4	1.90	NS[2]
CP, % of DM	20.2	18.4	0.45	*
ADF, % of DM	34.1	34.8	0.40	NS
NDF, % of DM	43.8	46.8	0.54	*
Ca, % of DM	1.18	0.82	0.03	**
P, % of DM	0.39	0.43	0.02	NS
Fermentation				
pH	5.9	5.8	0.12	NS
Lactate, % of DM	1.18	2.47	0.47	*
Acetate, % of DM	0.80	0.88	0.27	NS
Butyrate, % of DM	0.01	0.02	0.01	NS
Mold, log cfu/g of DM	3.7	3.1	0.33	NS
Yeast, log cfu/g of DM	4.2	4.8	1.51	NS
In vitro digestion				
NDF				
Digestible fraction, % of NDF	52.2	64.2	1.27	**
Undigestible fraction, % of NDF	47.8	35.8	1.26	**
k_d, 1/h	0.09	0.10	0.01	NS
Lag, h	2.2	2.7	0.82	NS
PD NDF,[3] % of NDF	30.3	39.1	1.16	**
IVTDMD,[4] % of DM	79.5	82.9	0.49	**

[1]AS = Alfalfa silage; PRS = perennial ryegrass silage.

[2]$P > 0.05$.

[3]PD = Potentially digestible; calculated as $B(k_d/k_d + k_p)$ where B = digestible fraction, k_d = degradation rate, and k_p = ruminal passage rate (0.06/h).

[4]In vitro true DM digestibility.

*$P < 0.05$.

**$P < 0.01$.

TABLE 2. Ingredient and nutrient composition of treatment diets.

Item	Treatment diet[1] AS	PRS
Ingredient, % of DM		
AS	69.7	. . .
PRS	. . .	68.1
Shelled corn	20.5	17.9
Meat and bone meal	2.0	2.0
Soybean meal	1.0	4.8
Expellers soybean meal	5.1	5.2
Dicalcium phosphate	0.51	0.93
Calcium carbonate	. . .	0.33
Monosodium phosphate	0.44	. . .
Trace-mineralized salt	0.56	0.57
Vitamin premix[2]	0.19	0.17
Nutrient composition		
CP, % of DM	20.6	19.9
ADF, % of DM	25.4	25.9
NDF, % of DM	35.7	37.1
Ca, % of DM	1.22	1.11
P, % of DM	0.53	0.56
RUP,[3] % of CP	34.0	35.0
NE_L,[3] Mcal/kg of DM	1.61	1.59

[1]Diets containing alfalfa silage (AS) or perennial ryegrass silage (PRS).

[2]Contained 2,645,500 IU/kg of vitamin A, 881,800 IU/kg of vitamin D, and 880 IU/kg of vitamin E.

[3]Calculated using NRC (17) values.

the treatment diets were purposely formulated to be low in energy to elicit the milk production potential of the experimental silages.

Mineral and vitamin concentrations were similar between treatment diets and were at or above NRC (17) requirements. Because PRS contained more NDF than did AS, the diet containing PRS had 1.4 percentage units more NDF than did the diet containing AS.

Lactation performance and intake characteristics of lactating cows fed diets containing AS or PRS are presented in Table 3. Cows fed AS produced 1.6 kg/d more ($P < 0.01$) milk than did cows fed PRS. No significant differences in milk fat percentage, milk protein percentage, or milk fat yield were observed between cows fed AS or PRS. Milk protein yield was lower ($P < 0.01$) for cows fed PRS compared with that of cows fed AS. A discrepancy between milk production and 4% FCM production was observed and can be explained by the tendency ($P < 0.13$) for a higher milk fat percentage for cows fed PRS.

A reason for the tendency for a higher milk fat percentage for cows fed PRS might have been related to the lower ($P < 0.01$) DMI for cows fed PRS compared with the DMI for cows fed AS. All cows on this experiment were in early lactation (61 ± 13 d) and, because cows fed PRS ate less DM, cows fed PRS probably mobilized more body fat than did cows fed AS. Mobilization of body fat is also positively correlated with milk fat percentage (10). We cannot completely confirm this hypothesis because no BW or body condition score measurements were taken.

Intakes of CP, ADF, and NDF were also lower ($P < 0.05$) for cows fed PRS compared with intakes for cows fed AS. Despite the advantageous NDF digestibility of PRS (Table 1), cows fed PRS did not consume similar amounts of NDF as did cows fed AS. These data led us to reject our pretrial hypothesis that the superior NDF digestion characteristics of perennial ryegrass may be advantageous to lactating dairy cows.

Digestibility Study

Diet digestibility and passage rate data (Table 4) support lactation and intake data. Because DMI was lower for cows fed PRS, rate of passage was also lower ($P < 0.05$) for cows fed PRS. The positive relationship between DMI and rate of passage is well documented (15). Because digestive tract retention times were longer for cows fed PRS, digestibilities of DM, OM, CP, and ADF were higher for cows fed PRS than for cows fed AS. The digestibility of NDF between diets containing PRS and AS was numerically different, but the difference was not significant ($P < 0.27$).

In the present study, total tract nutrient digestibilities of cows fed PRS were higher than those of cows fed AS, but slower rates of passage and lower DMI ultimately resulted in lower milk production. These events are biologically cohesive, but reasons for the

TABLE 3. Lactation performance and intake characteristics of lactating cows fed diets containing alfalfa silage (AS) or perennial ryegrass silage (PRS).

Item	Treatment diet AS	PRS	SE	Effect
Performance				
Milk, kg/d	31.8	30.2	0.31	**
Milk fat, %	3.61	3.76	0.06	NS[1]
kg/d	1.14	1.13	0.02	NS
Milk protein, %	2.96	2.93	0.02	NS
kg/d	0.93	0.88	0.01	**
4% FCM, kg/d	29.8	29.0	0.36	NS
Intake, kg/d				
DM	22.5	20.3	0.33	**
CP	4.6	4.0	0.07	**
ADF	5.7	5.3	0.08	**
NDF	8.0	7.5	0.12	*

[1]$P > 0.05$.

*$P < 0.05$.

**$P < 0.01$.

TABLE 4. Digestibility and dietary passage rates in lactating cows fed diets containing alfalfa silage (AS) or perennial ryegrass silage (PRS).

Item	Treatment diet		SE	Effect
	AS	PRS		
Digestibility, % of intake				
DM	68.6	71.8	1.06	*
OM	70.5	73.5	1.03	*
CP	63.9	69.1	1.60	*
ADF	59.5	65.7	1.60	*
NDF	61.8	65.2	1.95	NS
Rate of passage, %/h	4.86	4.05	0.171	*

*$P < 0.05$.

lower DMI of cows fed PRS are somewhat unclear. Traditional rationale suggests that, because the diet containing PRS had more NDF, cows would need to consume less DM to reach NDF gut fill limitations (13). This rationale assumes that cows consume equal quantities of NDF from grass and legumes. Weiss and Shockey (24) demonstrated that cows can consume equal quantities of NDF from grasses or from legumes. Our data, however, do not confirm those observations, because cows fed PRS ate less NDF than did cows fed AS. Differences in NDF intake by cows fed PRS cannot be explained by differences in rate or extent of the NDF digestion in PRS measured in this experiment.

Differences in palatability may be a plausible explanation for differences in DMI between cows fed PRS and AS. We measured silage fermentation parameters and found no evidence of major fermentation differences between PRS and AS at feedout that could have resulted in reduced DMI. Palatability is, however, a complicated biological issue and can be related to factors other than fermentation. We found no literature that suggested that perennial ryegrass has antiintake factors associated with it, and the evaluation of specific intake characteristics of perennial ryegrass was beyond the scope of the present study.

Reduced DMI and milk production could also be caused when cows are fed perennial ryegrass infected with an endophyte (2). Seed used to establish perennial ryegrass for this study, however, was guaranteed to be free of endophytes.

The observations of Waghorn et al. (23), however, present a plausible hypothesis that explains why cows in our study ate less DM, resulting in less milk production. Waghorn et al. (23) compared particle degradation characteristics of perennial ryegrass and alfalfa using cows fed a restricted diet. For cows, the reduction of perennial ryegrass particles, by means of eating and rumination mechanisms, to a size (<2 mm) that allowed passage from the rumen was markedly more difficult than the reduction of alfalfa particles. Those data (23) would explain our observation that passage rates were slower when cows consumed PRS, and, as stated earlier, the slower passage rates are strongly related to feed intake restrictions, resulting in reduced milk production.

CONCLUSIONS

Based on a previous study that suggested that perennial ryegrass contained slightly higher NDF but that the NDF was more digestible than alfalfa, we hypothesized that perennial ryegrass should support equal milk production in lactating dairy cows. We observed comparative NDF concentrations in experimental PRS and AS. Based on laboratory evaluations, the NDF digestion characteristics of the PRS were better than or equal to the NDF digestion characteristics of AS, but cows fed the PRS consumed less DM and produced less milk. We think that DMI and milk production of cows fed PRS in the present study were not limited by the inherent nutritional qualities of perennial ryegrass but by the physical limitations in particle degradation as has been suggested by Waghorn et al. (23).

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