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Supplementing Pasture to Lactating Holsteins Fed a Total Mixed Ration Diet

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ABSTRACT

Beginning in September 1997, a 6-week study was conducted to compare performance and income-over-feed cost of lactating Holsteins cows fed either a total mixed ration diet (TMR) only, compared to TMR in the afternoon and pasture in the morning, or TMR in the morning and pasture in the afternoon. Fifty-four Holstein cows in midlactation, averaging 28.1 kg/d of milk, were used in the study. Cows were on pasture for 8 h/d after either the p.m. or the a.m. milking. Predominantly orchardgrass with lesser amounts of white clover and Kentucky bluegrass were grazed. Pasture was sampled once per week, and weekly composites were analyzed. Compressed sward height and herbage dry matter (DM) yield were estimated once per week. Milk yield was electronically recorded and was sampled biweekly. Body condition score and body weight (BW) was recorded at the beginning and end of the study. Income-over-feed cost was calculated for each treatment. Compressed sward height and DM yield averaged 12.7 cm and 1397 kg/ha, respectively. Pasture crude protein, neutral detergent fiber, and acid detergent fiber averaged 27.0, 55.7, and 26.9%, respectively, and net energy-lactation was 1.65 Mcal/kg of dry matter. Milk production was greater for cows on the TMR treatment (29.1 vs. 28.2 and 27.6). No significant difference occurred in percentage of milk fat (3.54, 3.42, and 3.46%), or protein (3.28, 3.20, and 3.22%) for the above respective treatments. The SNF content (8.77 vs. 8.67 and 8.63%) was higher in TMR cows. While BW change did not differ among treatments (23, 32, and 22 kg), body condition score change was greater in cows fed TMR only (0.14 vs. –0.06 and 0.01). As expected, TMR intake was greatest for cows fed TMR only and lowest for cows grazing after the p.m. milking (26.6 vs. 20.3 vs. 17.5 kg/d dry matter). Income-over-feed cost differed between treatments and was approximately 18.6 and 7.5% higher for cows grazing high quality pasture during the afternoon and the morning, respectively, compared with cows on the TMR treatment.
(**Key words:** pasture supplementation, dairy cows, income-over-feed cost)

Abbreviation key: CSH = compressed sward height, **IOFC** = income-over-feed cost, **PAM** = TMR during the afternoon and grazing in the morning, **PPM** = TMR in the morning and grazing in the afternoon.

INTRODUCTION

The use of intensive rotational grazing has been examined by researchers in the United States in recent years (Berzaghi et al., 1996; Hoffman et al., 1993; 1994a, 1994b, 1995; Parker et al., 1992; Polan and Wark, 1997; Polan et al., 1986, 1995, 1996, 1997). Few studies have been conducted to evaluate the possibilities of using high-quality pastures in conjunction with TMR feeding during the grazing season. Using pasture as part of the diet could reduce feed costs and benefit herd health during the grazing season. However, it is not known whether milk production and composition can be maintained by practicing this feeding system.

A USDA survey reported that in recent years only 10 to 20% of dairy producers in the Northeast and upper Midwest dairy states of the United States have adopted more intensive grazing management (Hanson et al., 1998). In a previous survey, Parker et al. (1992) suggested that intensive grazing was not widely adopted because of a lack of confidence in the ability of pastures to provide high quality forage and the lack of information on how to maintain milk production under a grazing system. Thus, a conjunction of TMR and grazing could serve as a trial approach for dairymen interested in adopting an intensive grazing system.

The objectives of this study were to compare milk production and composition, BW and BCS change, and TMR intake between cows fed only a TMR diet with cows fed TMR ad libitum during half of the day, and grazing high-quality pasture the other half of the day. Furthermore, recent data (Schmidt and Pritchard, 1987) suggests that lactating grazing cows spend more time grazing after the p.m. milking (4.1 h/d) compared

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with after the a.m. milking (2.3 h/d). Thus, cow performance and TMR intake were also compared between cows fed TMR during half of the day (morning or afternoon), and supplemented with grazing pasture either during the morning or the afternoon. An economic analysis was also performed, by comparing income-over-feed cost (**IOFC**) between treatments.

MATERIALS AND METHODS

Cows and Experimental Design

Fifty-four Holstein cows averaging 185 DIM and 28.1 kg/d of milk were used in a 6-wk study. Three treatments were compared during the study. One group of cows totally in confinement was fed a typical TMR diet (Table 1). The second group of cows was fed a TMR diet during the morning and grazed a mixed pasture during the afternoon (**PPM**). The third group of cows was fed a typical TMR diet during the afternoon and grazed pasture during the morning (**PAM**).

Before the preliminary period, 30 of the 54 cows had grazed for 12 consecutive weeks. All cows were confined and fed a TMR diet for 3 wk until the beginning of the experiment.

Table 1. Composition of the TMR fed during the experiment.

Item	TMR
	(% of DM)
Ingredients	
Alfalfa silage	34.6
Corn silage	11.8
High-moisture corn	15.9
Barley	19.3
Soybean meal	6.1
Whole cottonseed	7.8
ProLak[1]	2.4
Mineral-vitamin premix[2]	1.1
Limestone	0.5
Sodium bicarbonate	0.5
	(% of DM)
Nutrient composition	
DM, %	61.7
CP	18.0
NE_L, Mcal/kg of DM	1.68
NDF	28.9
ADF	17.6
NFC	40.7
Ether extract	4.0
Ash	6.0
Ca	1.0
P	0.5
Mg	0.3
K	1.5

[1]H. J. Baker & Bros., Inc., Stamford,CT.

[2]Contained (%): Ca, 14.5; P, 6.5; Mg, 2.2; K, 3.5; Cl, 8.0; Na, 6.4; S, 3.2; $NaHCO_3$, 18.0: (mg/kg): Mn, 1100; Zn, 1325; Fe, 265; Cu, 132; I, 20.0; Co, 3.0; Se, 5.0; F, 650; (IU/kg): Vitamin A, 110,000; vitamin D, 55,000; vitamin E, 550.

The experimental design was a restricted randomized complete block design. Cows were blocked according to whether they were previously on pasture or not, and then were stratified according to milk yield, parity, and DIM, after which they were randomly allotted to three groups. Cow characteristics per treatment are reported in Table 2.

Grazing and Feeding Management

Four fields of approximately 2.7 ha each were used in an intensive rotational manner. Pastures were composed of primarily orchardgrass (*Dactylis glomerata*) with lesser amounts of Kentucky bluegrass (*Poa pratensis*) and white clover (*Trifolium repens*). An electrified nylon string was moved across the field twice daily to allow each group (a.m. and p.m. grazing) to graze an area sized to supply adequate supplemental pasture.

The treatments PPM and PAM spent approximately equal time in the field or in confinement. Cows in treatment PPM had access to a TMR diet from 0300 to 1200 h, and grazed during the afternoon after the p.m. milking (1500 to 2300 h). Cows in the PAM treatment were in the field during the morning (0300 to 1100 h) and were fed a TMR ration in the afternoon (1500 to 2400 h). Cows in the TMR treatment (TMR) were in confinement the 24 h and were fed only a TMR. The same TMR diet was offered ad libitum to all treatments, while in confinement. Cows on the TMR treatment were fed twice daily as follows: two-thirds were offered after the p.m. milking and one-third after the a.m. milking. Feed refusals were weighed and the feeding rates adjusted daily to yield orts of about 10%. The TMR intake per treatment was calculated daily from the difference between the amount fed and feed refusals. All cows had continuous access to water.

Sward Measurements and Analysis

A minimum of four quadrants (0.25 m^2) of herbage were harvested per week at the height of 5 cm before grazing for forage analysis and to estimate available forage, using the technique described by Frame (1981). Before harvesting the herbage, compressed sward height (**CSH**) was measured in each quadrant by using an acrylic disk meter (Murphy et al., 1995; Rayburn and Rayburn, 1998). Immediately after collection, pasture samples were weighed and oven-dried at 55°C for 48 h or until constant weight. Herbage DM yield (kg/ha) and availability (kg/d per cow of DM) were calculated as described previously (Schmidt and Pritchard, 1987).

Pasture samples were later ground to pass a 1-mm screen of a Wiley mill (Arthur H. Thomas, Philadelphia, PA), and composites of weekly samples were prepared.

Table 2. Cow distribution and characteristics before the beginning of the study (wk 0).

	Treatments[1]					
Item	PPM	SD	PAM	SD	TMR	SD
Primiparous, no.	11		11		10	
Multiparous, no.	7		7		8	
Milk yield, kg/d	28.9	4.3	29.5	5.5	29.6	5.6
DIM	184	69	186	69	185	69
BW, kg	566	62.9	545	53.1	584	67.1
BCS	2.9	0.32	2.9	0.29	2.9	0.29

[1]PPM = Cows were in confinement, eating a typical TMR diet during the morning and grazed a mixed pasture in the afternoon; PAM = cows were in confinement, eating a typical TMR diet during the afternoon and grazed a mixed pasture in the morning; TMR = cows were in confinement for 24 h and were fed a typical TMR diet in the morning and the afternoon.

Composite samples were analyzed for CP, ash by AOAC (1990), and ADF and NDF (Goering and Van Soest, 1970; Van Soest et al., 1991), and for macro and micro minerals by the Cumberland Valley Analytical Services Laboratory (Maugansville, MD). RDP and RUP were not estimated for the protein fraction of forages. Pasture was very lush as evidenced by 27% CP. Based on previous studies with similar quality forage by Berzaghi et al. (1996), RDP was estimated to be 75% or greater. Hemicellulose and NE_L and were calculated by using the following equations:

$$\text{Hemicellulose } (\%) = \text{NDF\%} - \text{ADF\%};$$
$$NE_L(\text{Mcal/kg of DM}) = 1.0876 - 0.0127 \times \text{ADF\%} \times 2.2$$
(Undersander et al., 1993);
$$\text{and NFC } (\%) = \text{DM} - (\text{CP} + \text{NDF\%} + \text{ash\%} + \text{EE\%})$$
(Mertens, 1992).

The Pennsylvania State University equation (Undersander et al., 1993) for grasses was used to determine NE_L in pastures. Average nutrient composition of pastures, alfalfa silage, and corn silage are reported in Table 3.

Sample Collection and Analysis

Forages and grains included in the TMR were sampled at wk 1, 3, and 6 during the study. Immediately after collection, samples were oven dried at 55°C in a forced-air oven during 48 h or until constant weight. Samples were later ground to pass a 1-mm screen of a Cyclotec mill (Tecator 1093, Hoganas, Sweden) and composited.

Forage samples used in the TMR diet were analyzed for the same nutrients as pasture samples (Table 3) by the Cumberland Valley Analytical Services Laboratory. Grain samples were analyzed for CP, ash, ADF, and NDF in the Virginia Tech Forage Testing Laboratory (Blacksburg, VA). Nutrient composition of grains is shown in Table 4. The TMR had a forage-to-concentrate ratio of 50:50, and contained 18% CP and 1.69 Mcal/kg of DM of NE_L (Table 1).

Cows were milked twice daily beginning near 1200 and 2400 h, and milk production was electronically recorded at each milking. Milk samples were collected once during the preliminary period and during wk 1, 3, and 6 of the study. Individual a.m. and p.m. samples were analyzed for fat, protein, and SNF at the Blue Ridge DHIA Laboratory (Blacksburg, VA), by using infrared spectrometry (Multispec Mark I; Foss Food Technology, Eden Plains, MN).

The BW and BCS (Wildman et al., 1982) were determined in the preliminary period and at the end of the study. Cows were weighed on two consecutive days at

Table 3. Nutrient composition of forages used during the study.

Item	Pasture[1]	Alfalfa silage	Corn silage
DM, %	18.0	51.9	35.3
Composition, %DM			
OM	89.1	87.9	95.0
CP	27.0	20.2	11.8
NE_L, Mcal/kg[2]	1.65	1.46	1.55
NDF	55.7	39.3	47.3
ADF	26.9	32.0	27.5
Hemicellulose	28.8	7.3	19.8
NFC[3]	5.0	27.4	32.8
Ash	10.9	12.1	5.0
Ca	0.55	1.43	0.41
P	0.39	0.32	0.22
Mg	0.32	0.31	0.24
K	4.50	2.54	1.68
Fe, ppm	123	875	213
Mn, ppm	51	86	35
Zn, ppm	40	38	25
Cu, ppm	6	7	5

[1]Pastures were predominantly orchardgrass with lesser amounts of Kentucky bluegrass and white clover.

[2]NE_L of pasture = 1.087 − 0.0127 × ADF% × 2.2; NE_L of alfalfa silage = 1.044 − 0.0131 × ADF% × 2.2; and NE_L of corn silage = 1.044 − 0.0124 × ADF% (Penn State equations) (Undersander et al., 1993).

[3]Nonfibrous carbohydrates = 100% DM − (CP% + NDF% + Ash% + ether extract%) (Mertens, 1992). An estimated ether extract was used in the equation.

Table 4. Nutrient composition of feedstuffs[1] included in the TMR's concentrate.

Item	HMC	Barley	SBM	WCS
DM, %	75.8	92.3	92.3	92.4
Composition, %DM[2]				
OM	98.4	97.4	93.3	95.2
CP	7.7	11.2	49.3	19.4
NE_L, Mcal/kg	2.04	1.94	1.94	2.23
NDF	12.4	33.8	8.5	44.0
ADF	3.1	12.7	6.2	34.0
NFC[3]	74.0	50.3	34.0	11.8
Ether extract	4.3	2.1	1.5	20.0
Ash	1.6	2.6	6.7	4.8
Ca	0.02	0.05	0.29	0.21
P	0.32	0.38	0.68	0.64
Mg	0.14	0.15	0.28	0.46
K	0.35	0.47	1.98	1.00
Fe, ppm	30	85	175	151
Mn, ppm	6	18	35	19
Zn, ppm	18	19	66	33
Cu, ppm	4	9	24	9

[1]HMC = High moisture corn; SBM = soybean meal; WCS = whole cotton seed.

[2]The NE_L, ether extract (EE), and macro and micro minerals were obtained from NRC (1989); NDF and ADF for whole cotton seed were obtained from NRC (1989).

[3]Nonfibrous carbohydrates = 100 − (CP% + NDF% + Ash% + EE%) (Mertens, 1992).

0930 h. If weights differed by 15 kg or greater, cows were weighed a third time. The BCS was determined by four independent evaluators, using the scoring system based on a five-point scale (1 = very thin to 5 = very fat) Wildman et al., 1982.

Statistical Analysis

Data were analyzed by analysis of covariance, using repeated measures, and the general linear models procedure of SAS (1982). The model used in the study was as follows:

$$Y_{ijkl} = \mu + T_i + P_j + (TP)_{ij} + bx_k + C_{(ij)k} + W_l + (TW)_{il} + (PW)_{jl} + (TPW)_{ijl} + E_{ijkl}$$

where

Y_{ijkl} = dependent variable,
μ = overall mean of Y,
T_i = treatment,
P_j = prior pasture,
$(TP)_{ij}$ = treatment i within prior pasture j block interaction,
b_lX_k = covariate of Y on X (X = pretreat Y for cow K),
$C_{(ij)k}$ = cow k within $(TP)_{ij}$ treatment by block interaction,
W_l = effect of wk l (1 = 1, 2, 3, . . . , 6),
TW_{il} = effect of week interaction between wk l and treatment i,
PW_{jl} = effect of week interaction between wk l and block j;
TPW_{ij} = effect of week interaction between wk l, treatment i, and block j, and
E_{ijkl} = residual error term.

This same statistical model was used to analyze and compare TMR intake between treatments; however, the covariate was not included, as no preliminary data were obtained for TMR intake. Effects of diets were determined by orthogonal contrasts PPM vs. PAM, and TMR vs. (PPM + PAM). All means presented were least-squares means.

Economic Analysis

The milk price used in economic analysis ($14/45.5 kg of milk) was determined by rounding the average milk price for Virginia for 6 yr (1991 through 1996) (Virginia Agricultural Statistics Service, 1997). Three values were established for the TMR and pasture cost, i.e., high, medium, and low. The medium price for TMR was $123.20/tonne of DM, obtained from the ingredient prices shown in Table 5. The ingredient prices were obtained from Virginia Cooperative Extension Service (1996–1997) and personal communication (R. E. James, 1998). The medium TMR cost was increased or decreased 20% to obtain a high and a low TMR price, respectively.

For the purposes of this study, pastures were assumed to be already established. Thus, a pasture maintenance budget of $94/ha was estimated, based on information reported by the Virginia Cooperative Extension

Table 5. Total mixed ration and feeding cost.

Item	Cost[1] $/tonne as fed	$/tonne of DM
Ingredients		
Alfalfa silage	46.3	89.2
Corn silage	28.0	79.3
High moisture corn	90.0	119
Barley	92.0	99.7
Soybean meal	190	206
Whole cottonseed	150	162
ProLak[2]	500	542
Mineral-vitamin premix[3]	350	350
Limestone	75.0	250
Sodium bicarbonate	300	300
Total TMR cost	76.0	123.2
Labor costs[4], $/d	17.4	

[1]All ingredient costs except corn and alfalfa silage (Virginia Agricultural Statistics Service, 1997) were obtained from local prices (R. E. James, personal communication).

[2]Rumen undegradable protein source (H. J. Baker & Bros., Inc., Stamford, CT).

[3]Mineral-vitamin premix (custom-mixed by Southern States Cooperatives, Richmond, VA).

[4]Labor time was estimated to be 2.18 h/d @ $8.00/h for cows on the TMR treatment. This labor time included 30 min/d for cleaning feedbunks (twice per day) and stalls (once per day); 90 min/d for feeding TMR (twice per day); and 10 min/d for moving cows to the parlor and back to the stalls.

Service (1996–1997) (Table 6). Land costs and daily labor was excluded from the costs, with the assumption that land was equally available whether grazing or TMR feeding occurred. Based on measures in previous seasons, total herbage yield was estimated to be 6750 kg/ha DM per grazing season. Based on this yield, medium cost of pasture DM was $0.631/45.4 kg DM. High and low pasture costs were determined by adding or subtracting 20% of the medium pasture costs. All calculations of IOFC are reported on an individual cow basis.

RESULTS AND DISCUSSION

Herbage Yield and Availability

Compressed sward height averaged 12.7 cm and herbage DM yield averaged 1397 kg/ha DM above grazing height (5 cm) throughout the study. The daily herbage DM availability was calculated based on herbage DM yield and the grazing area allowed daily. About 0.2 ha was allotted per grazing session. Based on the largest estimated amount of forage DM intake shown later, consumption accounted for about 60% of the forage available above 5 cm height.

A regression equation for herbage mass as a function of CSH was developed by using 24 pairs of observations obtained throughout the study. The following regression equation was obtained: herbage DM yield = 52.157 + 107.83 × CSH. The standard error for the intercept and slope were 287.6 and 22.3, respectively. The relationship between CSH and herbage DM yield was linear ($P \leq 0.05$), and the correlation was 0.72. This correlation was similar to the one (0.73) obtained from the same pastures during May, June, and July (Soriano et al., 2000). Rayburn and Rayburn (1998), over a number of site years, got a cumulative R^2 determination of 0.52.

Milk Production and Composition

Least-squares means of milk production and composition for the treatment groups are summarized in Table 7. Cows in the TMR group produced 1 to 2 kg more milk ($P \leq 0.05$) than cows in the PPM and PAM treatments. However, milk production differed little in the second half of the study (Figure 1), although TMR intake increased in the second half, especially in the PPM group (Figure 2). Fat percentage (3.47%) and fat yield (0.97 kg/d) did not differ among treatments. Similarly, milk protein percentage and yield were not different between treatments, averaging 3.23% and 0.90 kg/d, respectively. In contrast, the SNF percentage was greater in cows fed only TMR compared with PPM and PAM (8.77 vs. 8.63 and 8.67%).

Table 6. Pasture, grazing, and feeding budget for dairy cows in the PAM and PPM treatments.[1]

Budget item	Cost $/ha	$/tonne of DM
Pasture maintenance[2]		
White clover + inoculant[3]	3.8	0.56
N fertilizer (urea)[4]	57.0	8.44
Fertilizer application	11.9	1.76
Herbicide	8.4	1.24
Fuel, oil, and lube	3.4	0.50
Repairs	9.5	1.41
Land cost[5]	74.1	10.98
Total pasture cost	93.9	13.92
TMR cost		123.2
Labor cost, $/d[6]	19.50	

[1]PAM = Cows were in confinement, eating a typical TMR diet during the afternoon and grazed pasture during the morning; PPM = cows were in confinement, eating a typical TMR diet during the morning and grazed pasture during the afternoon.

[2]Budget obtained from Virginia Cooperative Extension Service (1996–1997), cost of land not included.

[3]Reseeding of 0.5 kg/ha of white clover plus inoculants once per year.

[4]Fertilization of 100 kg/ha of N per year.

[5]Based on typical local rental.

[6]Labor time was estimated to be 2.44 h/d @ $8.00/d. This labor time included 60 min/d for moving electric strings and water once per day, and cows twice per day; 6.0 min/d for measuring compressed sward height by using the disk meter technique (twice per week) and by calibrating the disk once per month by clipping and drying pasture samples (Frame, 1981); 20 min/d for cleaning feedbunks and stalls once per day, and 45 min/d for mixing feeding TMR once per day.

Table 7. Milk production and composition and TMR intake of Holstein cows for each dietary treatment.

Item	Treatment[1]			SEM	P^2		
	PPM	PAM	TMR		TRT	WEEK	TRT × WEEK
TMR intake, kg/d of DM	17.5[a]	20.3[b]	26.6[c]	0.15	**	**	**
Milk yield, kg/d	28.2[a]	27.6[b]	29.1[b]	0.30	*	NS	NS
3.5% FCM, kg/d	27.1	27.3	28.7	0.19	NS	*	NS
Milk composition		%					
Fat	3.42	3.46	3.54	0.13	NS	NS	*
Protein	3.20	3.22	3.28	0.05	NS	NS	NS
SNF	8.67[a]	8.63[a]	8.77[b]	0.07	*	NS	NS
		kg/d					
Fat	0.94	0.95	1.01	0.05	NS	*	NS
Protein	0.88	0.88	0.93	0.03	NS	NS	NS
SNF	2.39	2.38	2.50	0.08	NS	NS	NS

[1]PPM = Cows fed TMR in the morning and pasture in the afternoon; PAM = cows fed pasture in the morning and TMR in the afternoon; TMR = cows fed only TMR.

[2]TRT = Effect of treatment; TIME = effect of week; TRT × WEEK = effect of interaction between treatment and week.

[a,b,c]Means with different superscripts within rows differ ($P \leq 0.05$); based on contrast 1 = PPM vs. PAM, and contrast 2 = TMR vs. (PPM + PAM).

*$P \leq 0.05$.

**$P \leq 0.01$.

In earlier experiments (Polan et al., 1986), milk fat content declined when ≈7.3 kg of corn was supplemented to grazing cows compared with those fed a balanced TMR in dry lot. Also, fat percentage responded inversely to the amount (3.6 to 7.3) of corn supplement. Milk SNF sometimes responded positively to TMR diets or corn supplementation to pasture, but response in milk protein was variable.

BW Change and BCS

No significant differences were observed in mean BW change throughout the study (25.7 kg) (Table 8). However, cows were weighed in the morning, which may have biased the BW upward of the two groups of cows fed TMR in the morning. In contrast, final BCS and BCS change were higher ($P \leq 0.05$) in cows fed TMR only compared with cows in PPM and PAM treatments (0.14 vs. –0.06 and 0.01). This suggests that cows that

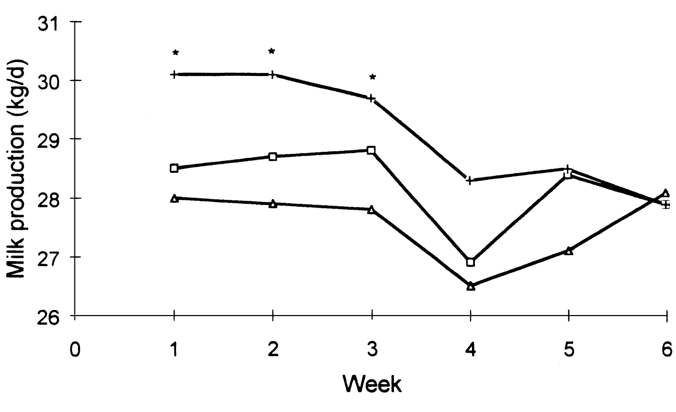

Figure 1. Comparison of milk production between Holstein cows in TMR, PPM, and PAM treatments. Treatments consisted of cows that were in confinement for 24 h and were fed a typical TMR diet (TMR) (+); cows that were fed a typical TMR diet in the morning and grazed pasture in the afternoon (PPM) (□); and cows that were fed a typical TMR diet during the afternoon and grazed pasture in the morning (PAM) (△. *Superscript indicates weeks at which milk yield was significantly higher for cows on the TMR treatment compared with the PPM + PAM treatments.

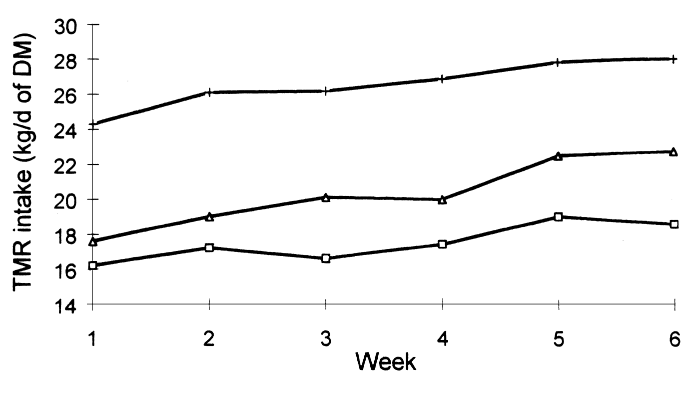

Figure 2. Comparison of TMR intake between lactating Holstein cows in the TMR, PPM, and PAM treatments. Treatments consisted of cows that were in confinement, eating a typical TMR diet in the morning and grazed in the afternoon (PPM) (□); cows that were in confinement, eating a typical TMR diet in the afternoon and grazed pasture in the morning (PAM) (△); and cows that were in confinement for 24 h and were fed a typical TMR diet (TMR) (+). TMR intake was significantly different ($P \leq 0.01$) between treatments in all the weeks of the experiment.

Table 8. Mean BW and BCS change of lactation Holstein cows on each treatment.

	Treatments[1]			*P*	
Item	PPM	PAM	TMR	TRT[2]	Contrast[3]
Initial BW, kg	566	545	584		
Final BW, kg	598	567	607	NS	NS
BW change, kg	32	22	23	NS	NS
Initial BCS	2.9	2.9	2.9		
Final BCS	2.8[a]	2.9[a]	3.0[b]	*	*
BCS change	–0.06	0.01[a]	0.14[b]	*	*

[1]PPM = Cows were in confinement, eating a typical TMR diet during the morning and grazed a mixed pasture in the afternoon; PAM = cows were in confinement, eating a typical TMR diet during the afternoon and grazed a mixed pasture in the morning; TMR = cows were in confinement for 24 h and were fed a typical TMR diet in the morning and the afternoon.

[2]TRT = Effect of treatment.

[3]Contrast compares PPM vs. PAM and TMR vs. (PPM + PAM).

[a,b]Means within row with different superscripts differ ($P < 0.05$).

*$P \leq 0.05$.

spent half the day on pasture had a lower proportion of BW deposited in the form of fat, perhaps because of greater activity (NRC, 1989). However, BCS is a subjective value but, in this study, indicated a probable increase in body cover of cows fed TMR only.

Estimation of TMR Intake

As expected, TMR intake was greatest ($P \leq 0.01$) in cows in the TMR group (Table 7). Cows in PPM and PAM treatments consumed, respectively, 65.8 and 76.3% of TMR DM consumed by cows in the TMR treatment. Furthermore, cows in PAM treatment consumed nearly 3 kg/d DM more TMR ($P \leq 0.01$) than cows in the PPM group. Average TMR intake (kg/d DM) per week is shown in Figure 2. Total mixed ration intake was significantly different ($P \leq 0.01$) between treatments in all 6 wk of the study, and TMR intake increased throughout the experiment in all groups ($P \leq 0.01$). In addition, difference in TMR intake between PAM and PPM treatment was 1.4 kg/d DM in wk 1 ($P \leq 0.05$) and increased to 4.2 kg/d DM ($P \leq 0.01$) in wk 6. Thus, cows in PPM treatment increased in TMR intake at a rate slower than the PAM groups, as the study progressed.

Estimated feed intake and nutrient composition of each treatment diet are shown in Table 9. Diet composition in cows in PPM and PAM treatments was based on the following assumption: The FCM, BW, and BW changes did not differ among treatments. Furthermore, milk yield differed only in the first half of the study and the average difference during the study was only 1 kg/d. Thus, based on these observations, it may be assumed that cows who spent less time in confinement and grazed during half of the day compensated for lower TMR intake by consuming more pasture to equal the same total DM intake. The substitution rate for hay, grass silage, or corn silage was one-to-one for pasture (Muller et al., 1998). Based on this assumption, cows in PPM and PAM treatments grazed an average of 9.1 and 6.3 kg/d of herbage DM per cow during the study. Thus, cows in PPM grazed 3 kg/d DM per cow more pasture than cows in PAM treatment. This corresponds to the results observed by Soriano et al. (2000), where grazing cows supplemented with corn spent more time

Table 9. Estimated proportion of TMR and pasture intake, and nutrient composition of diets fed to cows on the TMR, PAM, and PPM treatments.

	Treatment[1]		
Item	TMR	PAM	PPM
	% of DM		
TMR	100	76.3	65.8
Pasture	0	23.7	34.2
Nutrient composition			
DM, %	61.7	51.3	46.8
	% of DM		
CP	18.0	20.1	21.1
NE_L, Mcal/kg of DM	1.68	1.67	1.67
NDF	28.9	35.5	38.1
ADF	17.6	19.8	20.8
NFC	40.7	32.2	28.5
Ether extract	4.0	3.1	2.6
Ash	6.0	7.2	7.7
Ca	1.0	0.9	0.8
P	0.5	0.5	0.5
Mg	0.3	0.3	0.3
K	1.5	2.2	2.5

[1]TMR = Cows were in confinement for 24 h and were fed a typical TMR diet in the morning and the afternoon; PPM = cows were in confinement, eating a typical TMR diet during the morning and a grazed mixed pasture in the afternoon; PAM = cows were in confinement, eating a typical TMR diet during the afternoon and a grazed mixed pasture in the morning.

Table 10. Income-over-feed costs (1997) for dairy cows fed either a TMR, a TMR in p.m. and pasture a.m. (PAM), or TMR in a.m. and pasture p.m. (PPM) with milk valued at $14/45.4 kg.

		IOFC		
TMR[1] costs	Pasture[1] costs	TMR[2]	PAM[3]	PPM[4]
High	High	5.02	5.40	5.94
Medium	High	5.68	5.90	6.37
Low	High	6.34	6.40	6.79
High	Medium	5.02	5.41	5.97
Medium	Medium	5.68	5.91	6.40
Low	Medium	6.34	6.41	6.83
High	Low	5.02	5.43	6.00
Medium	Low	5.68	5.93	6.43
Low	Low	6.34	6.43	6.86

[1]TMR and pasture costs designated by medium represent 1998 costs. High and low represent costs 20% above or below medium cost.

[2]TMR was $5.58/45.4 kg of DM, 26.6 kg of DM intake, milk yield = 29.1 kg.

[3]PAM – TMR cost above, pasture was $0.631/45.4 kg of DM. TMR intake was 20.3 kg and pasture 6.3 kg of DM. Milk yield, 27.6 kg/d.

[4]PPM – TMR and pasture cost above. TMR intake was 17.5 kg of DM and pasture 9.1 kg of DM. Milk yield, 28.2 kg/d.

grazing after the p.m. milking (4.1 h/d) than after the a.m. milking (2.3 h/d). The height and density of pasture was similar and a fresh area was allotted with forage in excess, which suggests that a higher pasture intake occurred after the p.m. milking compared with after the a.m. milking. Based on these assumptions, the nutrient balance was numerically similar among treatments (Table 9). This was verified by the nearly identical NE_L concentrations of the three feeding regimens when the pasture NE_L (1.65 Mcal/kg) is averaged on a weighted basis with the TMR NE_L (1.68/Mcal/kg of DM).

Economic Analysis

Feed cost usually accounts for 35 to 50% of the total cost of production (Schmidt and Pritchard, 1987). Thus, this analysis can have a significant importance when determining the profitability of milk production (Schmidt and Pritchard, 1987). Based on previous assumptions of TMR and pasture intake, IOFC was calculated and compared among treatments.

Income-over-feed costs was always greater for cows in PPM treatment for the $14/45 kg of milk price using feed prices applicable to 1997 and increased or decreased by 20% (Table 10). Cows in PPM treatment had an IOFC of 72 and 49 cents per cow per day greater than cows in TMR and PAM treatments, respectively, when TMR and pasture price were medium. Furthermore, IOFC was 23 cents per cow per day greater in cows in PAM treatment compared with TMR treatment for medium, TMR, and pasture price. As cost of TMR was decreased, the difference in IOFC between treatments decreased (Table 10). If land was available to graze with no cost charge to land, the overriding influence on IOFC was the cost of the TMR. In this study, any short-term quality grazing as a part of the diet, along with a TMR, improved IOFC. With medium feed costs, it is possible to realize an IOFC increase of $0.50/cow per day with the price of milk used in this comparison.

CONCLUSIONS

When cows were fed TMR ad libitum during half the day, and allowed to graze during the other half of the day, between 65.8 and 76.3% of the total DMI was estimated from the TMR diet and the rest from pasture. Results from this study showed that the use of high-quality pastures by cows initially averaging 6 mo in lactation as a partial diet during half the day will maintain cow performance without decreasing milk composition and BW compared with a TMR with total confinement. Furthermore, supplementing grazed pasture to dairy cows consuming a TMR diet had an economical advantage over feeding only TMR.

The differences in TMR intake observed during the study suggest that under similar herd management conditions, most economical returns were obtained by feeding a TMR diet after the a.m. milking and by allowing cows to graze good quality and abundant pastures during the afternoon.

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