Effect of Grass Silage Supplementation on Performance in Lactating Cows Grazing on Pasture

K. I. Sung* and M. Okubo[1]
Department of Feed Science and Technology, Kangwon National University, Chunchon 200-701, Korea

ABSTRACT : Two trials were carried out during two different grazing seasons to evaluate effect of grass silage supplementation, when amount of pasture is limited on dry matter intake (DMI), milk production, and gross energetic efficiency (GEE) of grazed lactating cows on a high forage-based diet. Fifty-one Holstein cows were randomly assigned to one of two dietary treatments: high pasture group or high silage group. In the spring flush, pasture and silage DMI, milk yield, milk fat percentage, and GEE were not different between the dietary groups. After the spring flush, pasture and silage DMI were higher for the high silage group than for the high pasture group. After the spring flush, although these were the higher total DMI of the high silage group than the high pasture group, milk yield was significantly ($p<0.05$) higher for the high pasture group than the high silage group. Milk fat percentage tended to be higher for the high silage group than the high pasture group. The GEE was significantly ($p<0.05$) higher for the high pasture group than the high silage group during after the spring flush. This study indicated that supplementation of grass silage, especially after the spring flush, can have a significant effect of increasing of forage intake and maintenance of the milk fat percentage; but not increase milk yield and GEE. *(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 10 : 1409-1418)*

Key Words : Grazing Cow, Grass Silage Supplementation, Spring Flush, Gross Energetic Efficiency of Milk Production

INTRODUCTION

Researchers have studied that the grazing, instead of concentrate strategy for lactating cows seems to have no differences in efficiency of milk production (Rogers et al., 1979; Sekine et al., 1987; Sung, 1992a). Okubo (1990) suggested that gross energetic efficiency of milk production (GEE) varied from 20 to 59% because of many factors; forage quality, forage intake, supplemental feed, parity, lactation stage, milk yield, etc. Sekine et al. (1987) found that the net efficiency of utilizing metabolizable energy (ME) for lactation was the same value (0.54) when cows fed on concentrate at rates of 25 and 35% of milk yield. When high forage diets included cool season grass pasture feeding during the grazing season and corn silage in the winter, GEE was almost equal for lactating cows fed on a 64:36 and 73:27, forage:concentrate ratio (Asahida et al., 1989). However, milk yield tended to decrease because cows fed diets containing 73% forage (50% pasture, 24% silage and 26% hay) and 27% concentrate had a low DMI compared to that of diets containing 64% forage (30% pasture, 26% silage and 44% hay) and 36% concentrate. This is due to the low pasture DMI from June to September (Sung, 1992a) which are associated with less reproductive growth of cool season grasses.

Typical growth pattern of a cool season grass pasture is a spring flush followed by a summer slump and then a small resurgence in the fall (Phillips, 1988; Pysher, 1995). The large variation in herbage growth within years means that it is difficult to achieve high pasture intake at any one time. The low pasture DMI during grazing season, particularly after the spring flush including summer and fall, may limit available pasture (Jennings and Holmes, 1984). Therefore, when the available pasture is limited after the spring flush, it is important to feed supplemental forage or concentrate to prevent decrease of DMI. Ample research exists on supplementation of corn silage (Bryant and Donnelly, 1974; Holden et al., 1995; Phillips, 1988; Rogers et al., 1979) or concentrate (Berzaghi et al., 1996; Grainger and Mathews, 1989; Hoffman et al., 1993; Meijs and Hoekstra, 1984; Phillips and Leaver, 1985) for lactating cows grazing pasture. However, these types of supplement can decrease the DMI of pasture and forage. When available pasture is restricted, grass silage supplementation of lactating-grazing cows may be possible to increase the DMI of forage without decreasing milk production and GEE. Also, there is little information on the long-term effect of GEE in lactating-grazing cows fed on a high forage-based diet. This study was to evaluate the effect of grass silage supplementation on DMI, milk production, and GEE of lactating cows grazing on grass pasture at two different periods; during the spring flush and after the spring flush. Two trials were conducted during two different grazing seasons.

*Address reprint request to K. I. Sung. Tel: +82-33-250-8635, Fax: +82-33-251-7719, E-mail: kisung@kangwon.ac.kr.
[1] Faculty of Agriculture, Graduate School of Agriculture, Hokkaido University, Sapporo 060-8589, Japan.
Received February 27, 2001; Accepted May 31, 2001

MATERIALS AND METHODS

Cows and treatments

Trial 1 : Twenty-four Holstein cows averaged 2.6 parity, 632 kg body weight (BW), and 114 days in milk (DIM) at the beginning of the experiment were used. All cows had been exposed to grazing in previous seasons. They were randomly assigned to either a high pasture component (HP) group or to a high grass silage component (HS) group. Throughout the experimental period, the HP group grazed on the pasture for 5 hrs a day from 09:00 to 11:30 and 17:00 to 19:30 h. The HP group received 4 to 18 kg/d (as-fed basis) of grass silage according to the BW, the expected pasture intake, and the pasture allowance during the spring flush. The HS group also grazed on the pasture 5 hrs a day, same hours as the HP group during the spring flush (May 13 through June 20). After the spring flush (June 21 through October 31), the HS group grazed on the pasture only 2.5 hrs a day from 09:00 to 11:30 h and then grass silage was fed. The amount of grass silage offered in the HS group was regularly adjusted to allow 5 to 10% orts. To prevent heat exhaustion, both of the HP and HS groups grazing time were changed from 09:00 through 11:30 h into 05:00 through 07:30 h during July 21 through August 31. All cows received three equal meals of concentrate at a 5 to 25% of milk yield according to the parity and the stage of lactation in the day at 08:00, 11:30, and 15:30 hrs in the barn, and the maximum amount of concentrate in the diet was 8 kg/d. Cows also received grass hay (3 kg/d, as-fed basis) were fed once a day at 19:30 h, and the cows had free access to water and trace-mineralized salt blocks in the barn throughout the entire experiment. The first-cutting grass was mowed in early June (heading stage), field wilted, chopped by a forage harvester, and then ensiled in a tower silo. Similarly, the second-cutting grass was harvested, and wilted to approximately 85% DM for hay, and conserved as rectangular bales.

Trial 2 : Only the exceptions to the procedures from trial 1 are presented. Twenty-seven Holstein cows were randomly assigned to either a high pasture component (HP) group or a high grass silage component (HS) group. Due to either the calving or the dry off of cows during the grazing season in trial 1 and the previous experimental winter season, the constitution factors of cows (i.e., parity, BW, and DIM) were significantly different on both groups. At the start of the experiment the HP group parity was 2.2, BW 644 kg, and DIM 116 d, and for the HS group the parity was 2.3, BW 669 kg, and DIM 78 d. The spring flush, and after the spring flush in trial 2 were from May 8 through June 25, and June 26 through October 31, respectively. The procedures for making silage and hay were the same as those described for trial 1.

Pasture

Trial 1 : Pasture areas of the HP and HS group offered were 3.3 and 1.7 ha, respectively. The cows grazed on pastures that consisted primarily of orchardgrass (*Dactylis glomerata* L.), small amounts of white clover (*Trifolium repens* L.), and small amounts of assorted herbaceous weeds. During the spring flush, half of the pasture area for the HP group was allowed to grow for 4-5 weeks and then cut for silage without being grazed upon. After the pasture was cut and then regrown, cows were allowed to graze harvested area. Permanent wire fences divided areas into several paddocks and each of these paddocks was then further divided into sub-paddocks, which cows occupied for 3 days in a temporary portable electric fence. The pastures were managed under a rotational grazing system. In order to control insect population (Oriental armyworm, *Mythimna separata* W.), grazing on the pasture was not permitted during July 6 to July 17. Corn silage, instead of pasture, was given for this period.

Trial 2 : The procedures for management of pasture and grazing were the same as those described for trial 1.

Measurements and statistical analysis

Herbage mass available to the cows was obtained by clipping the pasture to a height of about 5 cm in ten quadrats (1 m × 1 m) per paddock during each grazing cycle. Pasture samples were plucked by hand from the ten different quadrat areas of the paddock and then composited. The concentrate, silage, and hay were sampled once per 10 days and composited. Feed offered and orts for each individual cow were weighed and sampled for 2 consecutive days per 10 days. Dietary formulations were then adjusted once per 10 days. All feeds were analyzed for DM, CP (AOAC, 1984), NDF and ADF (Goering and Van Soest, 1970), and gross energy (GE) (Automated adiabatic bomb calorimeter; Shimazu Co., Japan).

Cows were milked two times daily at 08:00 and 16:00 h and milk production was recorded daily at each milking. Milk samples from individual cows were collected and composited for two consecutive milkings per 10 days. Milk samples were analyzed for fat, protein, and lactose contents using a Milko-Scan Fossomatic (Foss Electric, Denmark). The solid-not-fat (SNF) percentage was determined using the equation SNF (%) = (protein, % + lactose, % + ash, %) where percentage of ash was assumed at 1%. Cows were weighed biweekly at 13:00 h.

Total tract digestibility trials of both the HP and HS group were conducted three times (the end of May, July, and September, respectively) during the grazing season. For the HP and HS group, three cows were selected at random and continued on the same diet, the same grazing time, and the same management as mentioned earlier. However, these cows were fed on fresh, clipped herbage instead of grazing on the pasture. The fresh, clipped herbage obtained was as close to that of the herbage grazed upon. The cows were housed in tie stalls and given free access to fresh water and to trace-mineralized salt blocks. Harnesses, feces bags, and urine separators were fitted to the cows 7 d prior, for adaptation before collection period, and followed by a 3 d collection period. During collection period, feed, orts, feces, and urine were collected daily per cow and were subsampled proportionally. A composited sample of feed, orts, and feces were oven-dried at 60°C for 48 h, and grounded through a 1-mm screen. A composited sample of urine was kept frozen (-20°C), then thawed to 4°C for 24 h, to analyze nitrogen content (AOAC, 1984) and energy; then these samples were permeated into a cellulose powder. Urine with cellulose powder was freeze-dried at -60°C and was analyzed for energy.

The GEE was expressed using the following equation: GEE (%) = (milk energy/ME intake) × 100. Where calculation of ME intake was determined as gross energy (GE) intake - (feces loss + urine loss + methane loss). Methane loss was calculated according to the equation of Blaxter and Clapperton (1965). Milk energy was calculated according to the equation of Sekine et al. (1985): Milk energy = 0.343 × milk fat (%) + 0.199 × SNF (%) + 0.005.

The major objective of this study was to evaluate the effect of grass silage supplementation when the amount of pasture is limited (in particular, after the spring flush) on DMI, milk production, and GEE of lactating-grazing cows. However, the responses in cow performance to additional grass silage is likely to be somewhat different for primiparous cows than for multiparous cows because primiparous cows usually attain substantial growth in body frame during lactation but multiparous cows are already at or very close to full size at the start of their lactation. This difference in size may account for what appeared to be a difference in milk production and energy utilization between primiparous and multiparous cows in this study. Where grass silage supplementation in lactating cows was offered over a long period, the responses also were varied at different stages of lactation. Therefore, performance data of multiparous cows after the spring flush in trials 1 and 2 were pooled, which was rearranged by stages of lactation. Days from 1 to 80 were considered to be early lactation, days 81 to 210 mid-lactation, and days from 211 to 305 late lactation. Cow's data in early lactation were used from 6 d after calving. Because some cows in late lactation did not complete 305 d of lactation, these cows had a minimum of 280 d of lactation data.

Statistical analysis for trial 1 was performed as a randomized complete block design using a PROC GLM (SAS, 1989). In order to clear the effect of grass silage supplementation, the data of multiparous cows after the spring flush in trials 1 and 2 were pooled, which was rearranged by stage of lactation. Data from multiparous cows were also analyzed using a PROC GLM (SAS, 1989). The model for trial 1 and data of lactation stage was determined according to the following: $Y_i = u + T_i + e_i$, where Y_i = dependent variables, u = Overall mean, T_i = effect of treatment I, and e_i = residual error. Differences were considered to be significant at $p<0.05$.

RESULTS

Animal performance in trials 1 and 2

Pasture and feed characteristics : Mass, height, and nutrient composition of pasture at the spring flush and after the spring flush are presented in table 1. In trials 1 and 2, the mean pasture mass ranged from 1.61 to 2.16 t DM/ha and the mean pasture height ranged from 26 to 34 cm. During the experimental period, CP content of pasture was slightly higher in the HP group than the HS group in both trials. The NDF content of pasture was lower in the HP group than in the HS group and ranged from 57.9 to 63.2% for both trials.

Grass silage fed to the cows in trial 1 was good quality in terms of fermentation than in trial 2 (Sung, 1992b). In

Table 1. Yield, height and nutrient composition of pasture during the spring flush (I) and after the spring flush (II) in trials 1 and 2

	Trial 1[1]						Trial 2[2]					
	HP			HS			HP			HS		
	I	II	$\bar{x}$	I	II	$\bar{x}$	I	II	$\bar{x}$	I	II	$\bar{x}$
Height, cm	28.0	28.7	28.5	31.0	34.0	31.8	32.8	26.8	27.7	30.2	26.0	26.1
Yield, ton/ha	1.61	1.79	1.62	1.65	2.05	1.92	2.15	2.16	2.07	1.98	1.90	1.93
Nutrient												
DM, %	22.9	21.6	22.0	24.5	22.5	23.4	18.3	23.0	21.0	21.9	26.9	24.2
CP, % of DM	18.5	15.9	16.4	16.3	15.5	15.6	19.7	17.1	18.0	17.6	15.4	16.0
NDF, % of DM	58.6	61.5	60.3	61.5	63.2	62.5	57.9	59.9	59.4	60.1	61.7	61.5
GE, Mcal/kg of DM	4.54	4.37	4.40	4.42	4.37	4.35	4.49	4.47	4.47	4.47	4.49	4.48

[1] The spring flush (I) and after the spring flush (II) in trial 1 were May 13 through June 20 and June 21 through October 31, respectively.

[2] The spring flush (I) and after the spring flush (II) in trial 2 were May 8 through June 25 and June 26 through October 31, respectively.

[3] Means during the whole grazing season (trial 1, May 13 to October 31: trial 2. May 8 to October 31).

trial 1, DM content of grass silage was higher compared to that in trial 2 (table 2), but contents of CP, NDF and GE did not differ between trials 1 and 2. Grass silage in both group contained lower CP content compared with NRC (1989) values. Both of these groups had high proportions of forage in their diet, which contained an 80:20 forage to concentrate ratio for trials 1 and 2.

DMI : In trial 1, the daily mean of the pasture DMI during the spring flush tended to be higher for the HP group than for the HS group, although there was no significant difference between the two groups (table 3). The pasture DMI for the HP and HS groups was below the expected pasture DMI (10 kg/d). After the spring flush, the daily mean of the pasture DMI met the expected pasture DMI in the both the HP (7 kg/d) and HS group (3.5 kg/d). Silage DMI did not differ between the groups in the spring flush. However, after the spring flush, silage DMI and forage DMI were significantly higher ($p<0.05$) for the HS group than for the HP group. Forage DMI of the HP and HS group for this trial was 12.8 and 13.5 kg/d and total DMI 16.0 and 16.8 kg/d, respectively. These differences were not significant, but DMI tended to be higher in the HS group than in the HP group.

In trial 2, pasture DMI during the spring flush was higher for the HP group than for the HS group (table 3); although they were lower than expected (10 kg/d). Silage DMI did not differ between the groups in the spring flush, however, silage and concentrate DMI after the spring flush were higher for the HS group than for the HP group. During the experimental period, forage DMI of the HP and the HS group were 11.4 and 11.9 kg/d, concentrate DMI were 4.3 and 4.8 kg/d, respectively; total DMI tended to be higher for the HS than for the HP group.

Milk production : In trial 1, milk yield and composition at the spring flush and after the spring flush are presented in table 4. Milk and 4% FCM yield of both groups was lower after the spring flush than for the spring flush. In the spring flush, actual milk and 4% FCM yield were significantly higher ($p<0.05$) for the HP group than the HS group. After the spring flush, milk and 4% FCM yield were significantly higher ($p<0.05$) for the HP group than for the HS group, despite the higher total DMI of the HS group than of the HP group. Mean of actual milk yield (18.8 vs. 16.8 kg/d) and 4% FCM yield (18.0 vs. 16.1 kg/d) were higher ($p<0.05$) for the HP group than for the HS group. Milk fat percentage tended to be higher for the HS group than for the HP group during after the spring flush. Milk protein and SNF percentages were similar for both groups.

In trial 2, the higher milk and 4% FCM yield for the HS group than for the HP group (table 4) contrasts with the results of trial 1. There were no consistent trends between the groups for milk fat, milk protein and SNF percentage.

Energy utilization : In trial 1, energy digestibility

Table 2. Nutrient composition of silage, hay and concentrate used in trials 1 and 2

	DM	CP	NDF	GE
	%	% of DM		Mcal/kg of DM
Trial 1				
Grass	31.4	12.3	65.0	4.57
Corn	25.9	6.6	40.5	4.47
Hay	84.3	8.4	73.3	4.40
Concentrat	84.7	21.9	23.5	4.44
Trial 2				
Grass	26.5	11.6	67.4	4.47
Hay	87.0	7.2	73.5	4.35
Concentrat	87.8	21.4	22.9	4.49

[1] Corn silage was fed from July 6 to July 17 due to armyworms damage on the pasture.

Table 3. Dry matter intake(DMI) of diets during the spring flush (I) and after the spring flush (II) in trials 1 and 2

	Trial 1[1,2]						Trial 2[3,4]					
	HP			HS			HP			HS		
	I	II	$\bar{x}$	I	II	$\bar{x}$	I	II	$\bar{x}$	I	II	$\bar{x}$
DMI, kg/d												
Pasture	7.8	7.2[a]	7.5[a]	6.9	3.8[b]	4.4[b]	8.2	6.4	6.8	6.3	3.3	4.0
Silage	2.3	4.3[b]	3.3[b]	3.2	9.0[a]	7.0[a]	1.0	3.2	2.7	1.4	7.2	5.9
Hay	2.1	2.3	2.0	2.0	2.2	2.1	1.7	2.0	1.9	1.6	2.1	2.0
Concentrate	3.5	3.1	3.2	4.1	3.1	3.3	5.3	4.0	4.3	5.5	4.5	4.8
FDMI[6]	12.2	13.8	12.8	11.6	15.0	13.5	10.9	11.6	11.4	9.3	12.6	11.9
TDMI[7]	15.7	16.9	16.0	15.7	18.1	16.8	16.2	15.6	15.7	14.8	17.1	16.7

[1] The spring flush (I) and after the spring flush (II) in trial 1 were May 13 through June 20 and June 21 through October 31, respectively.

[2] Significant differences shown trial 1 ; Comparisons were between the same periods and mean($\bar{x}$) during the whole grazing season.

[3] The spring flush (I) and after the spring flush (II) in trial 2 were May 8 through June 25 and June 26 through October 31, respectively.

[4] As mentioned in materials and methods, the trial 2 was not included in the statistical analysis.

[5] Means during the whole grazing season (trial 1, May 13 to October 31; trial 2, May 8 to October 31).

[a,b] Means within a row without a common superscripts differ ($p<0.05$). [6] Forage DMI. [7] Total DMI.

Table 4. Milk yield and milk composition during the spring flush (I) and after the spring flush (II) in trials 1 and 2

	Trial 1[1,2]						Trial 2[3,4]					
	HP			HS			HP			HS		
	I	II	$\bar{x}$	I	II	$\bar{x}$	I	II	$\bar{x}$	I	II	$\bar{x}$
Actual milk, kg/d	23.1[a]	17.5[a]	18.8[a]	21.8[b]	15.6[b]	16.8[b]	25.9	19.2	20.9	27.3	20.3	21.9
4% FCM, kg/d	22.6[a]	16.9[a]	18.0[a]	21.4[b]	14.7[b]	16.1[b]	24.3	18.0	19.5	25.2	19.5	20.9
Fat, %	3.80[b]	3.68	3.74	3.97[a]	3.71	3.72	3.62	3.60	3.60	3.52	3.80	3.73
Fat , kg	0.88	0.64	0.70	0.87	0.58	0.62	0.94	0.69	0.75	0.96	0.77	0.82
Protein, %	3.04[a]	2.92	2.95	2.65[b]	3.01	2.91	3.19	3.15	3.16	3.19	3.14	3.15
Protein , kg	0.70[a]	0.51	0.55	0.58[b]	0.47	0.49	0.83	0.60	0.66	0.87	0.64	0.69
SNF, %	8.74[b]	8.51	8.59	9.05[a]	8.66	8.74	9.14	8.90	8.96	9.11	8.85	8.91
SNF, kg	2.01	1.49	1.61	1.97	1.35	1.47	2.37	1.70	1.87	2.49	1.80	1.95

[1] The spring flush (I) and after the spring flush (II) in trial 1 were May 13 through June 20 and June 21 through October 31, respectively.
[2] Significant differences shown trial 1 ; Comparisons were between the same periods and mean($\bar{x}$) during the whole grazing season.
[3] The spring flush (I) and after the spring flush (II) in trial 2 were May 8 through June 25 and June 26 through October 31, respectively.
[4] As mentioned in materials and methods, the trial 2 was not included in the statistical analysis.
[5] Means during the whole grazing season (trial 1, May 13 to October 31; trial 2, May 8 to October 31).
[a,b] Means within a row without a common superscripts differ ($p<0.05$).

(DE/GE) and metabolizability (ME/GE) at the spring flush and after the spring flush were not different between the HP and HS group (table 5). Although GEE during the spring flush was not different between the HP and HS groups (49.4 vs. 48.1%), the time after the spring flush was higher ($p<0.05$) for the HP group than for the HS group (29.9 vs. 26.2%). During the whole experimental period, mean GEE was higher ($p<0.05$) for the HP group than for the HS group (35.5 vs. 29.2%).

In trial 2, digestibility of energy and metabolizability was similar for the HP and HS groups (table 5). The GEE during the spring flush was higher for the HS group (49.3%) than for the HP group (42.9%), but after the spring flush did not differ between the groups. During the experimental period, mean GEE was 36.0 and 37.0% for the HP and HS group, respectively.

Animal performance of multiparous cows after the spring flush

After the spring flush in trials 1 and 2, performance data in multiparous cows were summarized by early, mid, and late lactation (table 6). Pasture plus silage DMI in each stage of lactation tended to be higher for the HS group than for the HP group. Hay and concentrate DMI were similar for the HP and HS group. Mean for forage DMI and total DMI throughout all lactation stages tended to be higher for the HS group than for the HP group. Silage DMI to forage DMI ratio was 32% and 59% for the HP and HS group,

Table 5. Digestibility(DE/GE), metabolizability(ME/GE) and gross energetic efficiency (GEE) during the spring flush (I) and after the spring flush (II) in trials 1 and 2

	Trial 1[1,2]						Trial 2[3,4]					
	HP			HS			HP			HS		
	I	II	$\bar{x}$	I	II	$\bar{x}$	I	II	$\bar{x}$	I	II	$\bar{x}$
DE/GE, %	69.6	68.8	69.0	67.5	68.2	68.0	72.1	71.1	71.4	71.7	70.1	70.1
ME/GE, %	58.1	57.5	57.7	56.8	57.9	57.5	50.6	59.7	60.0	59.7	58.8	59.1
GEE, %	49.4	29.9[a]	35.5[a]	48.1	26.2[b]	29.2[b]	42.9	33.5	36.0	49.3	32.5	37.0

[1] The spring flush (I) and after the spring flush (II) in trial 1 were May 13 through June 20 and June 21 through October 31, respectively.
[2] Significant differences shown trial 1 ; Comparisons were between the same periods and mean($\bar{x}$) during the whole grazing season.
[3] The spring flush (I) and after the spring flush (II) in trial 2 were May 8 through June 25 and June 26 through October 31, respectively.
[4] As mentioned in materials and methods, the trial 2 was not included in the statistical analysis.
[5] Means during the whole grazing season (trial 1, May 13 to October 31; trial 2, May 8 to October 31).
[a,b] Means within a row without a common superscripts differ ($p<0.05$).

Table 6. Effect of grass silage supplementation after the spring flush (Ⅱ) on DMI of multiparous cows

	HP				HS			
	Early[1]	Mid[2]	Late[3]	x	Early	Mid	Late	x
DMI, kg/d								
Herbage	6.5^{a}	6.6^{a}	6.0^{a}	6.3^{a}	3.4^{b}	3.1^{b}	3.6^{b}	3.3^{b}
Silage	4.3^{b}	3.6^{b}	4.0^{b}	3.9^{b}	7.8^{a}	7.5^{a}	8.1^{a}	7.7^{a}
Hay	2.1	2.1	2.0	2.1	2.2	1.9	2.2	2.1
Formula feed	5.7	5.3	2.9	4.3	5.6	4.2	2.8	4.3
FDMI[5]	12.9	12.3	12.0^{b}	12.3	13.4	12.5	13.9^{a}	13.1
TDMI[6]	18.4	17.6	14.9^{b}	16.6	19.0	16.7	16.7^{a}	17.4
FDMI/TDMI, %	70.1	69.9	81.1	74.1	70.5	74.9	83.2	75.7

[1] Days from 1 to 80, [2] Days from 81 to 210, [3] Days from 211 to 305.
[4] Means during the whole grazing season (trial 1, May 13 to October 31; trial 2, May 8 to October 31).
[a,b] Means within a row without a common superscripts differ ($p<0.05$).
[5] Forage DMI, [6] Total DMI.

respectively. The forage DMI portion of the diets for each lactation stage in both groups ranged 69.9 to 83.2%.

Actual milk yield for early lactation stage were slightly higher in the HP group than in the HS group, although the difference was not significant (table 7). 4% FCM yield for early lactation stage did not differ ($p>0.05$) between the groups. Milk and 4% FCM yield for either mid or late lactation stages were higher ($p<0.05$) in the HP group than in the HS group. Mean of actual milk yield for all lactation stages was 3.0 kg/d higher for the HP group (21.3 kg/d) than the HS group (18.3 kg/d). Milk fat percentage in early and late lactation was higher in the HS group than in the HP group, although it was similar between the groups in mid lactation. The mean milk fat percentage of cows throughout all lactation stages was higher for the HS group than for the HP group. However, there are no consistent trends in milk protein and SNF percentage for both groups.

Crude protein intake (CPI) in the early and mid lactation stage tended to be for higher the HP group than for the HS group, except that for late lactation stage. However, ME intake (MEI) during late lactation stage was significantly higher for the HS group than the HP group and during early and mid lactation stages MEI tended to be high in the HS compared to the HP group (table 7).

The GEE was higher for the HP group than for the HS group for all lactation stages (table 7). With advancing lactation stage, GEE decreased in both groups. The GEE for all lactation stages for the HP group was significantly ($p<0.05$) higher than the HS group (34.6 vs. 30.4% respectively).

DISCUSSION

As mentioned earlier, in case of trial 2, parity, BW, and DIM between the HP and HS groups were different due to the calving cows and the dry cows during the previous winter season. Consequently, these differences between the two groups may influence upon DMI; the increase of concentrate DMI in the HS group was consistent with increased milk yield.

Table 7. Effect of grass silage supplementation after the spring flush (Ⅱ) on milk yield, milk composition and GEE of multiparous cows

	HP				HS			
	Early[1]	Mid[2]	Late[3]	$\bar{x}$	Early	Mid	Late	$\bar{x}$
Actual milk, kg/d	25.5^{a}	22.6^{a}	18.3^{a}	21.3^{a}	23.8^{b}	17.3^{b}	14.1^{b}	18.3^{b}
4% FCM, kg/d	23.1	20.6^{a}	17.4^{a}	19.7^{a}	22.4	16.9^{b}	14.6^{b}	17.8^{b}
Fat, %	3.37	3.49	3.69^{b}	3.55	3.59	3.47	4.24^{a}	3.68
Protein, %	2.27^{b}	3.04^{b}	3.18	3.04	3.04	2.85^{b}	3.30	3.01
GEE, %	36.4	34.4^{a}	33.8^{a}	34.6^{a}	34.8	30.6^{b}	25.1^{b}	30.4^{b}
CPI, kg/d	2.99	2.83^{a}	2.05^{b}	2.52	2.83	2.37^{b}	2.26^{b}	2.47
MEI, Mcal/d	47.6	46.1	38.0^{b}	42.8^{b}	49.5	48.5	44.2^{a}	47.8^{a}

[1] Days from 1 to 80, [2] Days from 81 to 210, [3] Days from 211 to 305.
[4] Means during the whole grazing season (trial 1, May 13 to October 31; trial 2, May 8 to October 31).
[a,b] Means within a row without a common superscripts differ ($p<0.05$).

DMI

Some researchers (Holden et al., 1994; Phillips, 1988) reported that the pasture DMI of grazing cows was influenced by amount of available pasture. Holmes (1987) concluded that the pasture DMI was not affected by a variation in pre-grazing pasture mass which ranged from 2.00 to 4.00 t DM/ha. Instead, the lower pre-grazing pasture mass of 1.50 t DM/ha might have affected pasture DMI. Throughout the present study, the pasture availability was ineffective to pasture DMI due to the pasture mass of above 1.61 t DM/ha. The difference in pasture DMI between the HP and HS group in the spring flush can be explained by a low NDF and a high CP content. Sung (1992a) and Hoffman et al. (1993) also have reported that the increased intake of herbage in May through early June and late June through July was associated with a low NDF and a high CP content of pasture. The trend for a higher DMI in late spring than in the summer was also observed by Holden et al. (1994).

When the quantity of available pasture is limited, particularly during the summer, dairy farmers will need to feed additional forage. The use of grass silage as supplementary forage for lactating-grazing cows when pasture availability was low, increased the forage DMI (Phillips, 1988; Muller and Holden, 1994). After the spring flush, silage DMI was higher for the HS group than the HP group in trial 1 (table 3) and in each lactation stage as well (table 6), and the increase in forage DMI was closely related to the increased amount of silage DMI in the present study. Phillips and Leaver (1985) found that forage DMI significantly increased with silage supplementation when the amount of pasture in the months of August through October was low. These results (Phillips, 1988; Phillips and Leaver, 1985) are consistent with the current study. Under the condition of a high forage-based feeding, and when the amount of pasture is restricted and the silage offered ad libitum in lactating-grazing cows as in this study, silage DMI is mainly dependent upon the quality of silage (Phillips, 1988; Mertens, 1994). Although supplementation of grass silage in this study was useful in increasing the forage DMI when pasture is limited, the small responses on forage DMI in the HS group may have been caused by the relatively low CP and high NDF of grass silage.

Supplementary feeding of grass silage after the spring flush may also prevent reduction and variation of forage DMI. When the wetness of the pasture surface was high, Butris and Phillips (1987) observed that decreasing the grazing time limited the pasture DMI. Due to heavy rain or unreasonable weather, pasture DMI became easy to reduce after the spring flush. Moreover, the little variation of DMI between months has been associated with the small amount of variation of milk yield (Stockdale, 1996) and this could be contributed to have the stable income during the grazing season. For the dairy farmers, the stable income throughout the grazing season might be more important than the gaining of income (Phillips, 1988). Results of the present study suggest that supplementary feeding of grass silage will be used as an effective means to maintain the forage DMI, particularly after the spring flush.

Milk production

The relationship between milk yield and DMI was well established. In the spring flush, the increased milk yield in the HP group was consistent with the results of increased pasture DMI (table 3). The variations of milk yield in lactating cows grazing on pastures were related to the variations of pasture DMI (Sung, 1992a).

The differences for actual milk and 4% FCM yield between the HP and HS groups were smaller for early lactation stage than for either mid- or late lactation stage. The reason for the lack of difference between the two groups in the early lactation stage can be explained by the homeorhetic control. Although the cow's energy intake to meet its nutrient requirements lack, in it's early lactation stage the cow preferentially produced milk by utilizing its mobilized body reserves. Therefore, this physiological control is possible to have much more affect in the early lactation stage than the treatment in this study.

After the spring flush, despite the higher total DMI of the HS group than of the HP group, actual milk and 4% FCM yield were lower for the HS group than for the HP group. Phillips (1988) found that milk yield decreased when grazing cows were fed either low quality silage or the same quality compared with that of pasture. The quality of grass silage throughout after the spring flush in this study was lower than that of pasture. The decrease in milk yield could be reflective of the lower quality in grass silage than pasture. Others studies (Aston et al., 1987; Phillips and Leaver, 1985; Roberts and Leaver, 1986) support that the quality of silage as a supplemental forage for lactating-grazing cows appeared to be an important factor influencing DMI and milk yield as in this study.

The increase of milk fat percentage for the HS group might be due to the increase of energy and fiber intake (Hoffman et al., 1993; Phillips and Leaver, 1985). In the current study, the MEI was numerically higher for the HS group than the HP group. Aston et al. (1987) also reported that MEI was higher for pastured cows that were offered supplementary grass silage than for cows on pasture only. Where grass silage was of lower quality than pasture, supplementation of grass silage has increased milk fat percentage (Aston et al., 1987; Rearte et al., 1984). It was also found that the HS group having a high portion of grass silage with pasture results in increased of milk fat percentage throughout after the spring flush.

GEE

Energy is the important limiting factor for the efficient milk production when large percentages of forage consist of the major source of diet for lactating cows. Similarly, Flatt et al. (1969) showed that energy digestibility of lactating dairy cows increased as concentrate DMI in the diet increases. In this study, energy digestibility and metabolizability were similar between the HP group fed with high grass silage and HS group fed with high pasture and this might be due to the same concentrate DMI between the HP and HS group. On the other hand, Sung (1992a) reported that energy digestibility and metabolizability did not differ for cows that were fed with diets containing higher proportion of pasture (lower proportion of concentrate) compared with that for cows that were fed with diets containing lower proportion of pasture (higher proportion of concentrate). This is in agreement with Muller et al. (1995) where high quality pasture should provide sufficient energy to support 18 to 23 kg of milk, and are highly digestible. These results suggest that effective utilization of available pasture has the potential to utilize as an energy supplement.

The variation of GEE is related to the changes of milk yield (Okubo, 1990; Smith, 1988), as it was the case in the present study. The GEE during the spring flush was the same for both the HP and HS groups because of similar milk yield. However, after the spring flush (trial 1 and each lactation stage) GEE was lower due to the decrease in milk yield of the HS group than that of the HP group. Okubo (1990) reported that a significant quadratic relationship was observed for GEE and milk yield for both the high-pasture diet that contained 60% pasture (cows fed a 0 to 25% concentrate for milk yield) and the medium-pasture diet that contained 30% pasture (cows fed a 25 to 35% concentrate for milk yield). The emphasis of that study was that notwithstanding the same milk yield, GEE was greater for cows on high-pasture diets than those on medium-pasture diets. The higher GEE for cows fed high-pasture diet was consistent with the results observed in the present study. These findings indicate that, when a high percentage of pasture is fed to lactating cows in high forage diet situation, the milk production can be significantly efficient.

Either CPI or MEI, and the interaction of CPI with MEI should have an influence on GEE of lactating-grazing cow (Oldham, 1984). In early and mid lactation stages, the HP group with greater CPI resulted in higher GEE. However, in late lactation stage the GEE was lower even when the HS group had higher CPI. Similarly, Tyrrell and Moe (1980) observed that the milk yield increased as the percentage of CP in the diets increased. However, when GEE was determined using the data of that study (Tyrrell and Moe, 1980) the CP levels in the diets showed no significant difference. Also MEI had no effect on GEE in this study, which was consistent with previous study (Smith, 1988). The correlation between GEE and the value of MEI per CPI (Mcal/kg) for the HP ($r = -0.59$; $p<0.01$) and HS groups ($r = -0.47$; $p<0.05$) was significant. Because the difference between the HP and HS groups did not occur, the pooled data for GEE of the HP and HS group appeared to be negatively related ($r = -0.65$; $p<0.01$) to increasing the value of MEI per CPI (figure 1). There were no significant effects of the CPI or MEI on GEE; only effects were caused by value of MEI per CPI. The GEE is shown to be remarkably lower for the HS group than for the HP group, value of MEI per CPI was higher for the HS group (16.7 to 19.1 Mcal/kg) than for the HP group (15.5 to 16.7 Mcal/kg), and this indicates that the HS group had lower ratio of MEI to CPI. These results suggest that balancing the ratio of MEI to CPI in a high forage-based diet have important effects on GEE in lactating cows on the pasture.

IMPLICATIONS

Under the feeding condition used in this experiment, supplementation of grass silage, especially after the spring flush or when pasture availability is low, can have a significant effect on forage dry matter intake and maintenance of the milk fat percentage. However, milk yield and gross energetic efficiency of milk production were lower for lactating grazing cows supplemented with the high percentage of grass silage. The present study indicates that the relationship between metabolizable energy intake and crude protein intake have important effects on milk yield and gross energetic efficiency.

ACKNOWLEDGMENTS

The authors thank Dr. D. H. Min in Michigan State

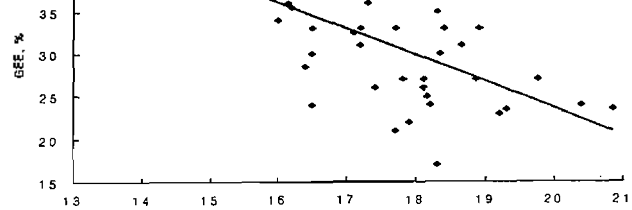

Figure 1. Relationship between the value of MEI per CPI and GEE when the HP and HS groups were pooled: $Y = -3.12X+86.06$ ($r=-0.61$, $p<0.01$, $n=46$) during the whole grazing season

University and Prof. L. D. Muller in Pennsylvania State University for advice in writing of this manuscript. This study was supported in part by Kangwon National University.

REFERENCES

AOAC. 1984. Official Methods of Analysis. 14th ed, Association of Official Analytical Chemists. Washington, DC.

Asahida, Y., K. I. Sung, J. Sekine, S. Kondo and M. Okubo. 1989. Feed intake, milk production and gross energetic efficiency of lactating cows fed high forage diet on 305-days production. In XVI International Grassland Congress, Nice, France, pp. 1165-1167.

Aston, K., S. R. Daley and B. G. Gibbes. 1987. Effect of offering silage overnight in the early grazing season to autumn-calved cows. Anim. Prod. 44:173-181.

Berzaghi, P., J. H. Herbein and C. E. Polan. 1996. Intake, site, and extent of nutrient digestion of lactating cows grazing pasture. J. Dairy Sci. 79:1581-1589.

Blaxter, K. L. and J. L. Clapperton. 1965. Prediction of the amount of methane produced by ruminants. Br. J. Nutr. 19:511-522.

Bryant, A. M. and P. E. Donnelly. 1974. Yield and composition of milk from cows fed pasture silage. N. Z. J. Agric. Res. 17:299-304.

Butris, G. Y. and C. J. C. Phillips. 1987. The effect of herbage surface water and the provision of supplementary forage on the intake and feeding behavior of cattle. Grass Forage Sci. 42:259-264.

Flatt, W. P., P. W. Moe, L. A. Moore, N. W. Hooven, R. P. Lehmann, E. R. Orskov and R. W. Hemken. 1969. Energy utilization by high producing dairy cows. I. Experimental design, ration, composition, digestibility data and animal performance during balance trials. Proc. 4th Symp. Energy Metab. EAAP Publ. 12:221-233.

Goering, H. K. and P. J. Van Soest. 1970. Forage fiber analysis (Apparatus, reagents, procedures and some applications) USDA, Agric. Handbook No. 379. USDA Washington, D. C.

Grainger, C., and G. L. Mathews. 1989. Positive relation between substitution rate and pasture allowance for cows receiving concentrates. Aust. J. Exp. Agric. 29:355-360.

Hoffman, K., L. D. Muller, S. L. Fales and L. A. Holden. 1993. Quality evaluation and concentrate supplementation of rotational pasture grazed by lactating cows. J. Dairy Sci. 76:2651-2663.

Holden, L. A. , L. D. Muller and S. L. Fales. 1994. Estimation of intake in high producing Holstein cows grazing grass pasture. J. Dairy Sci . 77:2332-2340.

Holden, L. A., L. D. Muller, T. Lycos and T. W. Casey. 1995. Effect of corn silage supplementation on intake and milk production in cows grazing grass pasture. J. Dairy Sci. 78:154-160.

Holmes, C. W. 1987. Pastures for dairy cows. In Livestock feeding on pasture. A. M. Nickel, ed. N. Z. Soc. Anim. Prod. Cocas. Publ. 10. Ruakura Agric. Res. Car. Hamilton, N. Z., pp. 133-143.

Jennings, P. G. and W. Holmes. 1984. Supplementary feeding of dairy cows on continuously stocked pasture. J. Agric. Sci., Camb. 103:161-170.

Meijs, J. A. C. and Hoekstra, J. A. 1984. Concentrate supplementation of grazing dairy cows. I. Effect of concentrate intake and herbage allowance on herbage intake. Grass Forage Sci. 39:59-66.

Mertens, D. R. 1994. Regulation of forage intake. In: Forage Quality, Evaluation, and Utilization (Ed. G. C. Fahey, Jr. M. Collins, D. R. Mertens, and L. E. Moser). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, WI, USA. pp. 450-493.

Muller, L. D. and L. A. Holden. 1994. Intensive rotational grazing. Large Animal Veterinarian July / August. 27-29.

Muller, L. D., E. S. Kolver and L. A. Holden. 1995. Nutritional needs of high producing cows on pasture. In Proc. Cornell Nutr. Conf. Feed Manuf., Rochester, Cornell Univ., Ithaca, NY, pp. 106-120.

National Research Council. 1989. Nutrient Requirements of Dairy Cattle. 6th rev. Ed. Natl. Acad. Sci., Washington, DC.

Okubo, M. 1990. Recent Problems in science and technology for milk production. Jpn. J. Zootech. Sci. 61(3):213-219.

Oldham, J. D. 1984. Protein-energy interrelationships in dairy cows. J. Dairy Sci. 67:1090-1114.

Phillips, C. J. C. 1988. The use of the conserved forage as a supplement for grazing dairy cows. Grass Forage Sci. 43:215-230.

Phillips, C. J. C. and J. D. Leaver. 1985. Supplementary feeding of forage grazing dairy cows. 2. Offering grass silage in early and late season. Grass Forage Sci. 40:193-199.

Pysher, D. E. 1995. Cool-season species selection and management. In Pennsylvania grazing conference. Grazing Research and Education Center, pp. 22-26.

Rearte, D. H., E. M. Kesler and G. L. Hargrove. 1984. Performance of dairy cows in mid lactation when grazing high quality pasture supplemented with concentrate and chopped or long hay. J. Dairy Sci. 67(Suppl. 1):143(Abstr).

Roberts, D. J. and J. D. Leaver. 1986. Supplementary feeding of forage to grazing dairy cows. 3. The effect of three daytime stocking rates on the performance of cows offered grass silage overnight. Grass Forage Sci. 41:71-78.

Rogers, G. L., A. M. Bryant, K. E. Jury and J. B. Hutton. 1979. Silage and dairy cow production. II. Milk yield and composition of cows fed pasture silage supplemented with pasture, maize silage and protein concentrates. N. Z. J. Agric. Res. 22:523.

SAS User's Guide: Statistics, Version 6 Edition. 1989. SAS Inst., Inc., Cary, NC.

Sekine, J., S. Kondo, M. Okubo and Y. Asahida. 1985. Prediction of energy value of cow's milk from the concentration of its components. Jpn. J. Zootech. Sci. 56:583-587.

Sekine, J., S. Tanaka, H. Nakatsuji, S. Kondo, M. Okubo and Y. Asahida. 1987. A consideration on energetic efficiency of lactation for cows fed concentrate at rates of 25% and 35% of milk yield. Jpn. J. Zootech. Sci. 58:805 - 811.

Smith, N. E. 1988. Alteration of efficiency of milk production in dairy cows by manipulation of the diets. In: Nutrition And Lactation in The Dairy Cows (Ed. P. C. Garnsworthy). London, Butterworths, pp. 216-231.

Stockdale, C. R. 1996. Substitution of herbage when dairy cows graze different pasture types in Northern Victoria. Proc. Aust. Anim. Prod. 21:381.

Sung, K. I. 1992a. Effect of herbage on feed intake, milk production and efficiency of lactating dairy cow fed high forage diets. Korean. J. Anim. Nutr. Feed 16(3):154-161.

Sung, K. I. 1992b. Yearlong feeding of silage and stability of feed quality. J. Korean Grassland Sci., 12(1):19-25.

Tyrrell, H. F. and P. W. Moe. 1980. Effect of protein level and buffering capacity on energy value of feeds for lactating cows. In: Energy Metabolism (Ed. L. E. Mount). London, Butterworths, pp. 311-313.