Comparison of part-time grazing and indoor silage feeding on milk production

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Cows were assigned randomly to indoor silage feeding (with 2 h outdoor exercise) or part-time grazing treatment in two different experiments. One group was kept in confinement with *ad libitum* grass silage within each experiment. The other group had *ad libitum* grass silage indoors and they were put out on grass pasture during part of the 24 hour period, 12 hours (night, Experiment 1) and 6 hours (day, Experiment 2) in June, July and August. In Experiment 2, the concentrate (9 kg d^{-1}) was given at two crude protein levels: high crude protein [185 g kg^{-1} dry matter (DM)] and low crude protein (135 g kg^{-1} DM). In Experiment 1, night-time grazing increased total DM intake and milk (3.9 kg d^{-1}) production. There was interaction between month and forage feeding strategy, the difference in milk yield being smallest between treatments in June. In Experiment 2, day-time grazing had no significant main effect on milk production but there was significant interaction between month and forage feeding strategy showing 2.5 kg d^{-1} difference between treatments in July. High-protein concentrate tended to increase the milk yield more on the silage diet compared with the group grazing during daytime. **The differences in milk yield between the forage feeding** treatments were mainly due to the higher dry matter intake and higher metabolizable energy content of the pasture grass compared with silage. **The lower milk responses to concentrate crude protein in the cows** grazing during daytime compared with the silage group indicate a high protein value of pasture grass. **It is** concluded that part-time grazing increases the milk yield and decreases the need for supplementary concentrate protein.

Key words: milk production, restricted grazing, dairy cows, protein supplementation

Introduction

Pasture is a challenging feeding strategy in Nordic latitudes because of a highly variable grass growth rate throughout the summer. The growth rate of timothy grass can be nearly 200 kg dry matter (DM) ha^{-1} per day in June, diminishing to 30 kg DM ha^{-1} per day in late August (Virkajärvi 2005). This variability makes it difficult to maintain a reasonable grazing rotation system during the summer. Another factor which causes difficulties in grazing is the lack of suitable pasture land near cowsheds, especially with increasing herd sizes. These challenges together with the short, 110-day grazing season have decreased the proportion of pasture in the cow's diet during the past few decades. However, most of the Finnish dairy farms use grazing and well managed pasture is the cheapest way to feed dairy cows also at Nordic latitudes (Seppälä et al. 2006).

A closed cowshed is an environment totally different from an open pasture, and grazing affects the behaviour and welfare of cows. Cows' natural behaviour is truly possible only at pasture and therefore well managed grazing enhances animal welfare. Giving up grazing also increases milk production costs because of increasing investments in harvesting machines and forage silos.

One solution to combine economic milk production and animal welfare could be part-time grazing where diet is constituted of pasture and silage. With daytime grazing it is possible to limit the grazing time to a few hours if the pasture area is small. The most intensive grazing occurs normally in the evening (Orr et al. 2001) and the grazing time during the night is often longer than during the day due the over 12 h difference between evening and morning milking used commonly in Finland. Thus night-time grazing is suitable if the proportion of grazed grass should be more than half of the daily forage consumption due to lack of silage available, or hot weather conditions causes discomfort or heat stress to cows during daytime. It should be noted that nights are light in the North-ern part of Europe and grazing is possible till late autumn.

The nutritional value of grazed grass and conserved grass differs mainly as a result of the differences in growth stages of the grass at harvesting. Ensiling of herbage *per se* had little effect on overall animal performance (Cushnahan and Mayne 1995), but ensiling degrades the grass protein extensively and decreases the rumen microbial protein synthesis, reducing the protein value of grass silage compared with fresh grass (Verbič et al. 1999, Givens and Rulquin 2004). This leads to the requirement of different amounts of protein supplementation to pasture and silage diets. Kolver (2000) and Nielsen et al. (2003) concluded that low-yielding, pasture-fed cows need less additional concentrate protein, while Huhtanen (1998) reported no relation between milk yield and protein supplementation responses in silage-fed cows. High protein value of digestible grass could satisfy the protein requirement of late lactating cows when the total protein requirement is lower. Thus it would be possible to decrease the concentrate protein content if high-quality pasture is included in the dairy cow's diet.

The aim of this study on dairy cows was to compare the effects of part time grazing (12 h night-time or 6 h day-time) with indoor silage feeding without pasture. Another aim was to study the responses to protein supplementation between silage feeding and part-time grazing.

Material and methods

Forage feeding treatments, management and pastures

The study was conducted at the MTT North Savo Research Station, Finland, during the grazing seasons 2003 (Experiment 1) and 2005 (Experiment 2). The forage feeding treatments studied were indoor feeding with grass silage and con-

AGRICULTURAL AND FOOD SCIENCE

Sairanen, A. et al. Comparison of part-time grazing and indoor silage feeding

centrate (silage feeding) or part-time grazing supplemented with silage and concentrate (night-time grazing in 2003 and day-time grazing in 2005). The cows were housed in a tie stall where the silage feeding groups were allowed outdoor activities in the yard for two hours daily. The daily grazing time was 12 hours (1800–0600) during the night in 2003 and six hours (0900–1500) during the day in 2005. Both silages and pastures consisted of timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.). The silages were prepared from a pri-mary-growth sward using a formic acid-based additive (5 l t^{-1}) and offered *ad libitum* (10% re-fusals) in the stall. The pastures were fertilized three times during each growing season. Fertiliz-ers were applied as three dressings (total 220 and 190 kg N ha^{-1} year^{-1} in Experiments 1 and 2, re-spectively), the first before the grazing season and the other two at intervals of approximately four weeks.

The cows in the pasture treatments grazed in intensive rotation with front and back fences be-tween 27 May and 31 August in 2003 and be-tween 30 May and 31 August in 2005. The target pasture herbage mass was 2000–3500 kg DM ha^{-1}. The cows grazed as a single herd with a fixed herbage allowance (HA) of 13 kg DM above 3 cm per night in Experiment 1. The herb-age mass was measured by a method modified by Stockdale (1984) before introducing a new strip. In this method the sward height of the dai-ly grazing area was measured by a rising plate meter (diameter 0.3 m, 3.5 kg m^{-2}). Three repre-sentative sampling areas were chosen based on the previously measured mean pressed sward height of the current paddock. In each area the disk height was recorded and then a frame of 20 × 50 cm was placed on the ground, and the herb-age inside the frame was cut to a height of 3 cm. Herbage allowance was not measured in Experi-ment 2, but the grazing rotation was conducted so that HA was not a limiting factor for milk production (assessed HA > 25 kg DM d^{-1}). The cows in Experiment 2 grazed as part of a large herd staying not more than three days at the same paddoc.

Experimental design and concentrate feeding

Experiment 1 was conducted in a randomized block design using eight primiparous [104 days in milk (DIM), standard deviation (SD) 47] and 26 multiparous (108 DIM, SD 42) Holstein-Friesian cows with an average pre-experimental milk yield of 33.0 kg d^{-1}. The cows were paired to 17 blocks according to parity, days in milk and pre-experi-mental milk yield, and allocated at random to for-age feeding treatments. The grazing season was divided into three periods by months: June, July and August. The 7-day intake measurement period was conducted in the middle of each month. The amount of daily concentrate was fixed to at 9 kg d^{-1}. Concentrates (Table 1) were given as three equal meals at 0600, 1530 and 1730. The concen-trate (g kg^{-1}) consisted of wheat bran (248), barley (234), oats (200), molassed sugar beet pulp (60), rapeseed meal (60), molassess (60), barley malt culms (50), palm kern meal (40), rapeseed cake (22) and minerals (26).

In Experiment 2, 12 primiparous (140 DIM, SD 52) and 20 multiparous cows (125 DIM, SD 69) were allocated to eight blocks according to pa-rameters described in Experiment 1. The treat-ments consisted of forage feeding strategies (silage feeding and day-time grazing) and concentrate at two crude protein (CP) levels: high protein (185 g kg^{-1} DM) and low protein (130 g kg^{-1} DM). The cows were randomly assigned to treatments within the blocks. The low-protein concentrate (g kg^{-1}) consisted of rolled barley (500) and oats (500). The high-protein concentrate consisted of barley (390), oats (390) and rapeseed meal (220). The daily concentrate allowance was 9 kg plus 200 g d^{-1} of mineral mixture. The four dietary treatments were arranged in a 2 × 2 factorial cross-over design with six periods. Each month (June, July and Au-gust) was divided into two periods. Each 15-day period comprised ten days of adjustment and five days of data collection for statistical analyses. The cows remained on the same forage feeding strategy (silage feeding or day-time grazing) throughout the summer, but the protein supplementation treat-

Table 1. Chemical composition of experimental feeds.

	Silage			Grass			Concentrate	
	June	July	August	June	July	August		
Experiment 1								
In DM, g kg^{-1}								
Neutral detergent fibre	567	604	609	435	513	512	293	
Crude protein	179	152	154	256	228	203	167	
Metbolizable energy, MJ kg^{-1}	11.3	10.8	10.8	12.0	11.5	11.6	11.9	
Digestible organic matter in dry matter	705	672	676	748	716	723		
Amino acids absorbed from the intestine	87	82	82	98	92	91	101	
Silage dry matter intake index [a]	99	91	93					
Sward height, cm				28	32	30		
Herbage mass, kg DM				2350	2550	2770		
Experiment 2							Control [b]	Suppl [c]
In DM, g kg^{-1}								
Neutral detergent fibre	555	548	550	539	464	495	260	262
Crude protein	148	179	167	199	231	211	130	185
Metbolizable energy, MJ kg^{-1}	11.0	10.3	10.5	11.3	11.4	11.4	12.5	12.3
Digestible organic matter in dry matter	687	645	655	714	725	705		
Amino acids absorbed from the intestine	83	81	81	90	92	91	98.5	110.9
Silage dry matter intake index	103	96	97					

[a] Huhtanen et al. 2002.

[b] Low crude protein

[c] High crude protein

ment was changed in three-period sequences as presented by Byron and Kenward (2003).

Measurements, sample collection and analysis

Indoor feed intake and milk production were measured daily. Milk samples from six consecutive milkings at the end of the data collection period (intake measurement period in Experiment 1) were analysed separately for fat, protein, lactose and urea content using an infrared analyzer (Milcoscan FT6000; www.foss-nirsystems.com). Live weight was measured after turnout and at the end of each period. Grass intake was estimated by the sward cutting method with two independent sets of ten plots (0.1 m^2) per grazing strip in Experiment 1. In

Experiment 2, grass intake was calculated as a difference between energy requirement (including maintenance, milk production and live weight changes) and measured energy intake as silage plus concentrate (MTT 2006). The grass silage samples were collected weekly and stored frozen (–23°C) until pooled monthly for analysis. Grass samples for chemical analysis were collected once a week before the start of grazing. The collected grass samples were stored frozen and then oven-dried at 60°C for analyses.

The DM content of the grass was determined by drying the samples at 105°C for 20 h. The nitrogen content of the dried samples was determined by a Dumas type N analyzer (Leco Fp-428), N content of silage (Kjeldahl-N) by the AOAC (1990) method, neutral detergent fibre (NDF) according to Van Soest et al. (1991, sodium sulfite was used in NDF-detergent solution) and in vitro OM di-

AGRICULTURAL AND FOOD SCIENCE

Sairanen, A. et al. Comparison of part-time grazing and indoor silage feeding

gestibility by a modification of the method described by Nousiainen et al. (2003). In this method the results were calculated with a correction equation to convert the OM pepsin-cellulase solubility into *in vivo* digestibility by an equation based on a data set comprising Finnish *in vivo* digestibility trials. Silage pH, volatile fatty acids and ammonium N were analyzed by the titration method (Moisio and Heikonen 1989). The silage dry matter intake index (SDMI) was calculated based on silage fermentation quality and D value (g digestible OM kg^{-1} DM) according to Huhtanen et al. (2002). Silage and grass amino acids absorbed from the intestine (AAT, Madsen et al. 1995) were calculated based on grass and silage CP and D values (MTT 2004). The metabolizable energy (ME) content for grass and silage was calculated by assessing the energy content of 0.016 MJ g^{-1} digestible OM. The ME and AAT contents of the concentrate were assessed as described by MTT (2006).

Statistical analysis

Experiment 1

Differences between treatment means in milk production, estimated feed consumption and live weight were tested for significance using the analysis of variance for repeated measurements (SAS Mixed, Co-variance structure AR1) according to the following equation:

$$y_{ijk} = \mu + block_i + forage_j + month_k + forage_j \times month_k + error_{ijk}$$

where forage is the effect of forage feeding strategy; silage feeding or part-time grazing.

Experiment 2

The effect of forage feeding strategy on milk production, calculated feed consumption and live weight was analysed with the repeated measurement model (SAS Mixed, Co-variance structure AR1) using the following equation:

$$y_{ijk} = \mu + block_i + forage_j + month_k + forage_j \times month_k + error_{ijk}$$

The effect of protein supplementation on milk production was analysed according to the following equation for cross over design:

$$y_{ijkl} = \mu + block_i + forage_j + supplementation_k + period_l + forage_j \times supplementation_k + period_l \times forage_j + error_{ijkl}$$

where supplementation is the effect of concentrate CP content. Cow was included in the model as a random factor.

Results

Total average precipitation per month for Experiments 1 and 2 was 73 and 77 mm, respectively. Respective average temperatures during the grazing time were 13.7°C in Experiment 1 and 19.1°C in Experiment 2. The warmest period (average temperature during grazing 25.6°C, mean relative humidity 47.0%) started on 9 July and ended on 16 July in Experiment 2.

The chemical composition of feeds is presented in Table 1. The fermentation quality of the grass silage was good all over in terms of pH (3.9, SD 0.12), volatile fatty acids (11.7 g kg^{-1} DM), SD 3.66, lactic plus formic acid (58 g kg^{-1} DM), SD 14) and proportion of ammonia in the total nitrogen (39 g kg^{-1} total N), SD 1.1). The ME and AAT contents of silage and DM intake index of silage were higher in June than in July and August in both experiments (Table 1). The differences in nutritive value of silages were consequence of differences in harvesting day. The growth stage of the grass silage was advanced compared to pasture, which can be seen in the low contents of silage ME, AAT and CP in silages, while the NDF content of silage was high compared with that of grass.

Experiment 1

Night-time grazed cows had small amounts of concentrate refusals in June, for the rest of the time

they consumed all the concentrates given. Grazing increased numerically the total measured DM and ME intake in Experiment 1 (Table 2), showing an average 0.74 kg kg^{-1} substitution rate for silage when pasture was included in the diet. The total DM and ME intake was not statistically tested due to absence of individual grass intake measurements within each period. The DM intake decreased during the summer on silage feeding strategy, while the highest DM intake was measured in August in the night-time grazing group. The proportion of grazed grass averaged 34% of total DM intake and 55% of total consumed forage.

Grazing increased milk and energy-corrected milk (ECM) yields (P < 0.001, Table 3, Figure 1a). The differences were smaller in June compared with July and August (interaction between month and forage feeding strategy P < 0.05). The average milk yield was 3.9 kg d^{-1} (3.1 kg ECM) higher on

night-time grazing than on silage feeding group. Grazing decreased milk fat content significantly (P < 0.01) and tended to increase (P < 0.1) milk protein content. The forage feeding strategy had no major effect on live weight, but apparent live weight gain was greater (P < 0.05) on the night-time grazing treatment (0.45 kg d^{-1}) than on the silage feeding treatment (0.20 kg d^{-1}).

Experiment 2

Grazing decreased silage intake (P < 0.001), but forage feeding strategy had no effect on total DM or ME intake when pasture grass intake was calculated on the basis of the cow's energy requirement (Table 2). The proportion of pasture DM was 22% of the total DM consumed.

Table 2. Effect of forage type on feed intake during the summer.

	June		July		August			Significance	
	Silage	Pasture	Silage	Pasture	Silage	Pasture	SEM	Diet	Diet × Month
Experiment 1									
Feed intake, kg DM d^{-1}									
Silage	11.5	5.3	10.3	4.7	9.8	6.5	0.32	<0.001	<0.001
Grazed grass		6.7		6.9		6.7	–[a]	–	–
Total forage	11.5	12.0	10.3	11.6	9.8	13.2	–	–	–
Concentrate	7.8	7.7	7.8	7.8	7.8	7.8	–	–	–
Total	19.3	19.9	18.1	19.4	17.6	21.0	–	–	–
Metabolizable energy intake, MJ d^{-1}	221	234	203	222	198	240	–	–	–
Experiment 2									
Feed intake, kg DM d^{-1}									
Silage	11.1	7.5	11.5	6.9	10.6	6.7	0.38	<0.001	<0.001
Grass [b]		4.0		4.9		3.7	–	–	–
Total forage	11.1	11.5	11.5	11.8	10.6	10.4	–	–	–
Concentrate	7.6	7.6	7.4	7.2	7.6	7.7	–	–	–
Total	18.8	19.2	18.9	19.0	18.2	18.2	–	–	–
Metabolizable energy intake. MJ d^{-1}	217	223	211	218	204	208	–	–	–

Silage = indoor silage feeding + outdoor exercise 2h.
Pasture = indoor silage feeding + night-time grazing (12 h) in Experiment 1 and indoor silage feeding + day-time grazing (6 h) in Experiment 2.
[a] Grass intake has not been tested statistically due to lack of independent replicates.
[b] Grass intake was calculated as the difference between energy requirement and dry matter intake indoors (MTT 2006).

AGRICULTURAL AND FOOD SCIENCE

Sairanen, A. et al. Comparison of part-time grazing and indoor silage feeding

Table 3. Effect of forage type on animal performance during the summer.

| | June | | July | | August | | Significance | | | |
	Silage	Pasture	Silage	Pasture	Silage	Pasture	SEM[a]	Diet	SEM[b]	Diet × Month
Experiment 1										
Live weight, kg	588	586	599	601	600	613	8.7	NS	8.9	<0.01
Milk, kg d^{-1}	31.3	34.2	26.8	31.2	24.5	28.9	0.50	<0.001	0.55	<0.001
Energy corrected milk, kg d^{-1}	31.3	33.5	26.8	30.0	25.0	29.0	0.49	<0.001	0.56	<0.001
Milk composition, g kg^{-1}										
Fat	40.0	37.8	40.6	37.0	41.6	39.8	0.52	<0.01	0.62	<0.1
Protein	31.3	32.4	31.2	32.5	32.5	33.6	0.35	<0.1	0.39	NS
Urea, mg dl^{-1}	38.8	35.2	35.0	39.2	30.9	32.1	0.48	NS	0.56	<0.001
Milk component yield, g d^{-1}										
Fat	1249	1292	1083	1153	1012	1147	17.9	<0.01	22.8	<0.05
Protein	976	1102	833	994	794	968	17.3	<0.001	19.4	<0.05
Experiment 2										
Live weight, kg	598	592	607	585	616	610	8.5	NS	8.9	<0.01
Milk, kg d^{-1}	29.3	29.7	26.5	29.0	25.2	26.8	0.68	0.12	0.73	<0.01
Energy corrected milk, kg d^{-1}	28.9	28.8	26.2	28.0	25.2	25.7	0.49	NS	0.56	<0.01
Milk composition, g kg^{-1}										
Fat	40.9	38.8	40.9	39.1	41.4	38.3	1.02	0.10	1.10	NS
Protein	32.6	32.5	33.2	33.1	34.3	34.2	0.49	NS	0.51	NS
Urea, mg dl^{-1}	24.4	25.4	36.5	37.1	35.6	36.0	1.09	NS	1.20	NS
Milk component yield, g d^{-1}										
Fat	1189	1148	1078	1124	1036	1008	25.5	NS	29.0	<0.01
Protein	947	957	876	948	860	907	13.2	<0.05	15.8	<0.01

Silage = indoor silage feeding + outdoor exercise 2h.
Pasture = indoor silage feeding + night-time grazing (12 h) in Experiment 1 and indoor silage feeding + day-time grazing (6 h) in Experiment 2.
[a] Standard error of mean for diet.
[b] Standard error of mean for diet × month interaction; month = June, July and August.

Grazing tended to increase the average milk yield (P = 0.12) by 1.5 kg (0.7 kg ECM) in Experiment 2 (Table 3, Figure 1b). There was interaction between month and forage feeding strategy in milk yield (P < 0.001), with the greatest difference in July (2.5 kg milk) and the smallest in June (0.4 kg milk). Grazing tended to decrease milk fat content (P = 0.10), but had no effect on milk protein content.

Rapeseed meal supplementation increased milk (P < 0.001) and ECM (P < 0.001) yields as well as milk protein (P < 0.001) and urea contents (P < 0.001), while milk fat content tended to decrease (P = 0.11, Table 4). Milk yield response to supplementation tended to be greater (P < 0.07) on the silage feeding group (0.9 kg milk kg^{-1} rapeseed meal) compared with the day-time grazing group (0.6 kg milk kg^{-1} rapeseed meal) when rapeseed meal substituted for grain. Rapeseed meal supplementation increased milk protein yield (P < 0.01) more on silage feeding group (81 g d^{-1}) compared with day-time grazed group (45 g d^{-1}).
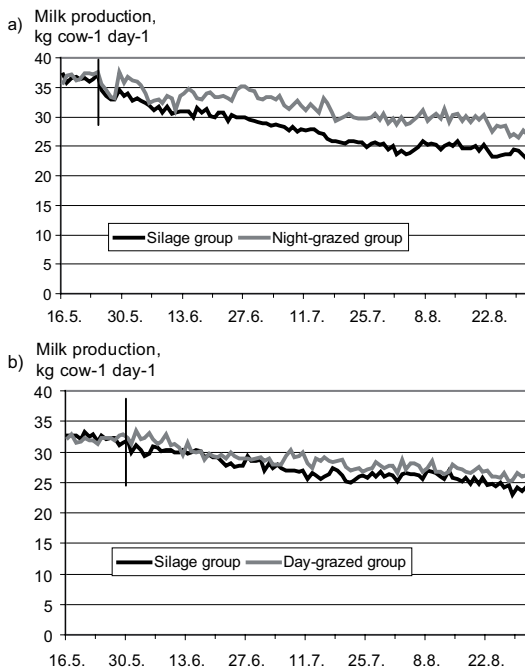
Fig. 1. Milk production a) during the summer 2003 and b) during the summer 2005. Vertical lines presents cows' turnout to pasture.

Discussion

Milk yield

Numerically part-time grazing produced more milk compared with the silage feeding in both experiments (Figs. 1a, b). The increment in milk yield was 0.33 kg milk per hour of grazing time for night-time grazing and 0.25 kg milk h^{-1} for day-time grazing. This agrees with the results reported by Dillon et al. (2002) where part-time grazing increased the milk yield by 0.31 kg h^{-1} of increased grazing time. One reason for the low grazing response late in June in Experiment 2 (Fig. 1b) was the difficulties in maintaining pasture rotation due to weather conditions resulting mature growth stage of grass. The rigid grass stem lowered both the utilization and energy content of pasture grass (D value 670 g kg^{-1} DM), which decreased the production value of pasture for three weeks. Pasture rotation was corrected by topping and the amount and the quality of the pasture improved at the beginning of July (D value > 710 g kg^{-1} DM), which can be seen also in the milk production. The cows

Table 4. Effect of protein supplementation on milk production in Experiment 2.

	Silage		Pasture			Significance	
	Low CP[a]	High CP	Low CP	High CP	SEM	CP	CP × forage[b]
Milk, kg d^{-1}	26.0	28.0	27.9	29.1	0.71	<0.001	0.07
Energy corrected milk, kg d^{-1}	25.8	27.6	26.9	28.2	0.52	<0.001	0.14
Milk composition, g kg^{-1}							
Fat	41.3	40.7	38.7	38.7	1.05	0.11	NS
Protein	33.1	33.7	33.2	33.4	0.49	<0.001	0.08
Urea, mg dl^{-1}	28.7	35.6	29.3	37.2	1.13	<0.001	NS
Milk component yield, g d^{-1}							
Fat	1065	1131	1071	1119	26.7	<0.001	NS
Protein	853	934	916	961	14.1	<0.001	<0.01

Silage = indoor silage feeding + outdoor exercise 2 h.

Pasture = indoor silage feeding + day-time grazing 6 h.

[a] CP = crude protein content in concentrate.

[b] Forage = forage feeding treatment: indoor silage feeding or day-time grazing (6 h).

AGRICULTURAL AND FOOD SCIENCE

Sairanen, A. et al. Comparison of part-time grazing and indoor silage feeding

in the day-time grazed group lost live weight from June to July, whereas the silage group gained weight more steadily throughout the summer. This suggests more negative energy balance for pasture group compared to silage group during the low pasture quality period.

The decline of the lactation curve was substantial in the silage group (141 g d^{-1}) compared with the group grazed during night-time (81 g d^{-1}) between 24 May 2003 and 1 August 2003 (Fig. 1a). According to the Finnish milk recording scheme, the expected decrease in daily milk yield should be 73 g d^{-1} at the lactation stage of the cows in the current study. Thus the recorded average difference of 3.9 kg in milk yield between the silage group and the group grazing during night-time was due to the exceptionally high decline in milk yield in the silage feeding group in June and July. The amount of concentrate used was quite low in Experiment 1, taking into account the energy content of silage especially in July and August (Huhtanen 1998, Rinne 2000). As predicted by the SDMI value of the silage in July, the cows in the silage-fed group were not capable of compensating the lower silage quality by increased total DM intake in the middle of the Experiment 1. Silage was substituted for high ME energy content pasture by night-time grazing and the silage quality limited the milk production of the pasture group less compared with the silage group.

Heath stress and animal welfare

In Experiment 2, during a hot period the cows exhibited symptoms of heat stress, panting and sweating (Kadzere et al. 2002) and they lied down in the cool stall when they went into the cowshed for milking. High daytime temperatures did not decrease the respective milk yields (Fig. 1b). Conversely, the average milk yield of cows grazed during day-time increased due to the better quality of pasture at that time. Thus the short period of heat stress did not disturb milk production despite the discomfort to the cows.

Heat stress is one part of animal welfare. Preliminary results of the other welfare parameters measured in Experiment 1 have been reported earlier by Virkajärvi et al. 2004. These parameters included locomotion score, hoof and muscle conditions, stereotypic behaviour, serum base cortisol and serum ACTH cortisol. The results showed quite small differences in welfare between the silage group and night-time grazing. One explanation to this would be that cows in the silage group were allowed to outdoor exercise for 2 hours. The activity of the cows on the exercise yard was quite low but it would be possible that outdoor activities have brought benefit for the stall housed cows.

Energy intake

The calculated energy content of the consumed forage was 0.5 MJ ME kg^{-1} DM lower on silage fed cows compared with night-time grazing group. According to Rinne 2000, an increase of 1 MJ ME kg^{-1} DM in silage energy content produces 1.69 kg extra milk. Thus the increased forage energy content could explain 0.8 kg of the observed 3.9 kg difference in milk production between silage feeding and night-time grazing groups. Increased dietary ME content together with increased total intake resulted in an increment of 25 MJ ME in energy intake in the group grazing during night-time. According to Huhtanen (1998), the increased grass intake is highly efficient in milk production (0.14–0.17 kg milk MJ^{-1} additional ME), which could explain all the difference in milk yield between silage feeding and night-time grazed group if the change in live weight gain is not taken into account. The average apparent live weight gain was 0.45 kg d^{-1} on night-time grazed group, which reserves 15 MJ d^{-1} (MTT 2006). The true live weight gain is possibly smaller than the measured weight, because a significant part of the weight gain could be due to increased rumen fill throughout the summer (Virkajärvi et al. 2002). However, the greater live weight gain of night-time grazed cows suggests better energy balance of pasture fed cows compared to indoor fed cows.

One reason for the increased dry matter intake in the group grazing during night-time compared

with the silage group could be the good palatability of fresh grass. The sugars in the grass are mostly fermented into organic acids in the silo which in large amounts reduce the silage intake (Huhtanen et al. 2002), while fresh grass is free from fermentation. The sugar content of the grass is high in the evening, which also increases the palatability of the grass and, consequently, the nutritive value of the night-time pasture compared with day-time pasture (Orr et al. 2001). However, according to Cushnahan and Mayne (1995), the effect of grass ensiling on milk production is small, at least in the case of restricted fermented silage. Another possible reason for the high intake of pasture diets is the high NDF degradation rate at the early growth stage of grass, which reduces rumen fill limitations and makes it possible to increase the dry matter intake (Kolver et al. 1998, Rinne et al. 2002, Sairanen et al. 2005).

Protein supplementation

Milk responses to protein supply tended to be higher in the silage group (0.9 kg ECM kg^{-1} rapeseed meal) compared with the group grazing during day-time (0.65 kg kg^{-1}) in Experiment 2 (Table 4), which supports the assumption of high protein value of pasture. The response of milk protein yield to increased AAT was also smaller in the group grazing during day-time (0.31 g g^{-1} AAT) compared with the silage group (0.50 g g^{-1} AAT) where the response of the silage group was close to 0.55 g g^{-1} AAT according to silage studies reported by Huhtanen (1998). The microbial synthesis in the rumen increases with increasing grass digestibility (Rinne et al. 1999) and, consequently, the protein value of pasture is higher compared with silage harvested in a more mature growth stage (MTT 2006). The ensiling process ferments water-soluble carbohydrates into organic acids which are not a good energy source for microbial ATP (adenosine triphosphate) production, decreasing microbial synthesis. However, despite the lowered response to protein supplement in milk protein production on day-time pasture diet, the calculated AAT balance was –98 g d^{-1} on low crude protein

pasture diet, which indicates an underestimation of the AAT value and/or intake of pasture.

The proportion of pasture in the day-time grazed diet was 22% of DM and therefore the differences in the responses of milk yield to protein supplement between silage feeding and day-time grazing treatments were not numerically remarkable. The responses to protein supplementation in the present study are in line with the results of the pasture study observed in the earlier experiment with the same herd at MTT Maaninka (Sairanen 2006, unpublished results). In that experiment there was only a small difference in the ECM production between low-protein (CP 140 g kg^{-1} DM) and high-protein (CP 180 g kg^{-1} DM) diets (28.1 vs. 28.4 kg ECM d^{-1}, respectively, P = 0.23). The reported responses to protein supplementation of pasture-fed cows vary, but they are generally fairly low (Tesfa et al. 1995, Wales et al. 2000, McCormick et al. 2001). It has been concluded that energy is a more limiting factor in milk production than protein on high-quality pasture below a milk production level of 30 kg (Wales et al. 1999, Kolver 2000, Bargo et al. 2003). According to this it is possible to decrease the concentrate protein content when pasture is included in the cow's diet.

An unnecessarily high protein content in the concentrate is both uneconomic and environmentally harmful. The increased milk urea content on high CP diets in Experiment 2 suggests decreased dietary N efficiency and increased urinary N excretion (Nousiainen et al. 2004). Urinary N is more vulnerable to leaching compared with manure N (Whitehead 2000). High dietary N increases urea production also in the liver and this causes some loss of metabolic energy. It is notable that the milk protein yield was almost the same on both high CP concentrate silage diet and low CP day-time grazing diet. High protein yield combined with low milk urea content indicates improved efficiency of dietary N.

Land use

Part-time grazing decreases the requirement of pasture area and makes it possible to choose be-

AGRICULTURAL AND FOOD SCIENCE

Sairanen, A. et al. Comparison of part-time grazing and indoor silage feeding

tween different grazing strategies according to the specific conditions on individual farms. The calculated average pasture area during the typical 110 d grazing season would have averaged 0.18 ha per cow in Experiment 1 and 0.11 ha per cow in Experiment 2. This estimation is based on measured intake of experimental cows in this study and an average weekly herbage growth rate of timothy pastures (variation 180 to 30 kg DM ha^{-1} d^{-1}) during the summer. The growth rate has been measured at the MTT North Savo Research Station in 1999–2004 (Virkajärvi 2005).

The average pasture area on full-time grazing should have been 0.26 ha d^{-1} at the concentrate feeding level of this study. The land area needed for full-time grazing would be even higher in practice due to difficulties in grass growth utilization in the variable weather conditions. A cow's energy requirement remains quite stable throughout the season and therefore decreased herbage growth must be compensated; the grazing area has to be doubled from June to August because of decreasing herbage growth rates in Nordic conditions.

Conclusions

The total feed intake and milk production increased by allowing the cows to graze part of the day instead of feeding them totally indoors. The allocated grazing time and subsequently the proportion of pasture were greater in cows grazing during nighttime compared with day-time grazing. This resulted greater differences in milk production between the compared treatments within night-time grazing than within day-time grazing. The increased dry matter intake explained the most of the differences in milk yield between the treatments. The metabolizable energy content of forages explained differences in milk yield during the summer within each experiment. Lower responses of milk to concentrate crude protein in day-time grazing cows compared with the silage group indicated a high protein value of pasture grass, which was the other reason for the greater milk yield of pasture-fed cows compared with the silage group. According to these results, the concentrate protein supplementation could be reduced by part-time grazing compared to silage feeding with silage.

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AGRICULTURAL AND FOOD SCIENCE

Sairanen, A. et al. Comparison of part-time grazing and indoor silage feeding

SELOSTUS

Osa-aikalaidun lisää lehmien maitotuotosta ja vähentää lisävalkuaisen tarvetta

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Osa-aikalaiduntamisella voidaan laidun pitää käyttökelpoisena ruokintamuotona myös suurelle karjalle. Tutkimuksessa selvitettiin osa-aikalaiduntamisen vaikutusta lehmien rehunsyöntiin ja maitotuotokseen kahdessa erillisessä kokeessa vuosina 2003 ja 2005. Molempina koevuosina laiduntamista verrattiin sisäruokintaan, jossa karja pääsi ulkotarhaan 2 h ajan. Ensimmäisessä kokeessa lehmät olivat laitumella yöllä (12 h laidunaika, Koe 1) ja toisessa päivällä (6 h laidunaika, Koe 2). Sisälläoloaikana kaikilla ryhmillä oli vapaa säilörehuruokinta, ja väkirehun määrä oli kaikilla lehmillä 9 kg. Kokeessa 1 väkirehun raakavalkuainen oli 167 g/kg kuiva-ainetta (ka). Kokeessa 2 lehmät saivat joko matalan (135 g/kg ka) tai korkean raakavalkuaistason väkirehua (185 g/kg ka).

Kokeessa 1 yöaikalaidun lisäsi kokonaissyöntiä ja maitotuotosta (3,9 kg/d). Kesäkuussa ryhmien välinen ero maitotuotoksissa oli pienin. Laidunryhmän elopaino lisääntyi kokeen aikana sisäryhmää enemmän. Kokeessa 2 päivälaidun ei lisännyt merkitsevästi keskimääräistä tuotosta kesän aikana. Maitotuotoksissa esiintyi kuukausi × käsittely -yhdysvaikutus siten, että heinäkuussa päivälaidunryhmä lypsi 2,5 kg/d enemmän sisällä pidettyyn ryhmään verrattuna. Väkirehun lisävalkuaisen käytöstä oli enemmän hyötyä sisäruokitulle ryhmälle kuin päivälaidunryhmälle.

Erilaiset tuotantotulokset selittyvät pääosin kokonaiskuiva-aineen syönnin eri määrillä. Laidunryhmillä karkearehuosuuden energiasisältö oli lisäksi säilörehuryhmää suurempi, joten kokonaisenergiansaanti muodostui laidunryhmillä kokonaissyönnin lisäystä suuremmaksi. Säilörehun ja laidunrehun energiasisällöt vaihtelivat molempien kokeiden aikana, ja erot laitumen hyväksi olivat suurimmillaan energia-arvoltaan matalan säilörehun aikana. Jopa heikkolaatuisinkin laidunrehu oli tuotantovaikutukseltaan vähintään hyvän säilörehun veroinen. Lisävalkuaisen heikko tuotosvaste laidunruokinnalla kuvastaa laidunrehun hyvää OIV-arvoa. Kokeen johtopäätöksenä voidaan todeta, että osa-aikalaidun lisää lehmien maitotuotosta ja vähentää lisävalkuaisen tarvetta ruokinnassa.