Dairy cow performance on silage from semi-natural grassland

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Received 4 May 2005; accepted 20 February 2006

Abstract

The effects of including forage from semi-natural grassland in the diet of dairy cows were studied in a feeding trial with cows in mid-lactation. Diets were compared in which part of the silage from intensively managed grassland was replaced with 0% (100IM), 20% (20SPP), 40% (40SPP) or 60% (60SPP) silage from species-poor semi-natural grassland or with 60% silage from species-rich semi-natural grassland (60SPR). On a dry matter basis, the total mixed ration (TMR) contained 63% grass silage, 18% maize silage and 19% concentrates. Concentrates were either low or high in protein to prevent protein surpluses or shortages. High producing cows were offered additional concentrates in concentrate boxes. The additional concentrates had the same composition as the concentrates in the TMR. With the 60SPP diet voluntary daily intake decreased by 1.4 kg DM cow^{-1} day^{-1}. Uncorrected milk production was the same for all diets, but milk fat yield was lower with the 60SPP diet and milk protein yield lower with the 60SPR diet than with the other diets. No statistically significant differences in fat and protein corrected milk production were observed between the 100IM and the 20SPP diet. The fat and protein corrected milk production with the other diets was significantly lower than with 100IM. All cows gained body weight, but there were no statistically significant differences between diets. In conclusion, if used in low quantities (< 40%), silage from semi-natural grassland can be included in the diet of lactating dairy cows without reducing production. This conclusion is based on the presented results and cannot be generalized.

Additional keywords: feeding value, forage, species-rich grassland, milk production, ruminants

Introduction

In western Europe most grassland is intensively managed and heavily fertilized with nitrogen. However, in order to protect plant diversity in grassland, the EU, national and regional governments and nature organizations encourage the development and maintenance of semi-natural, species-rich grassland. In the Netherlands, most grassland with management agreements for nature conservation are managed and used by dairy farmers (Korevaar & Van Der Wel, 1997). The feeding value tends to be lower for forage from semi-natural grassland than for forage from intensively managed grassland, so milk yields from cows offered the former are likely to be lower too (Bruinenberg *et al.*, 2002). Although farmers are financially compensated for economic losses due to lower production, they often are reluctant to use forage from semi-natural grassland, as there is insufficient information about their use in rations for lactating dairy cows. Consequently, the number of management agreements with farmers will be limited (e.g. Tallowin & Jefferson, 1999). However, if it can be proven that it is possible to include forage from semi-natural grassland in diets for dairy cows, conservation of these grasslands will be easier to combine with dairy farming.

The main difficulty associated with including forage from semi-natural grassland in the diet of dairy cows is that its feeding value cannot be easily quantified. There are a number of reasons for this. Firstly, the botanical composition of forage from semi-natural grassland varies during the year (De Vries & De Boer, 1959), because of differences between species in date of heading and reproduction. Secondly, chemical composition and nutrient availability vary amongst plant species and are difficult to predict (e.g. Korevaar, 1986; Frame, 1990; Bruinenberg *et al.*, 2002). Thirdly, there are different types of semi-natural grassland: some are managed to maintain large populations of meadow birds (habitat conservation), other ones are managed to conserve certain plant species or vegetation types or to achieve maximum species or genotypic diversity in the grassland vegetation (Korevaar, 1986).

Research on the use of forage from semi-natural grassland in the diet of lactating dairy cows is limited (e.g. Korevaar & Van Der Wel, 1997). Thus, the objective of the present study was to investigate the effects of diets containing different amounts of forage from semi-natural grassland on feed intake and milk yield of lactating dairy cows offered mixtures of silage from intensively managed and silage from semi-natural grassland.

The study involved silage from intensively managed grassland and silage produced from two types of semi-natural grassland, i.e., a species-poor grassland dominated by grasses (SPP), and a species-rich grassland consisting of a mixture of grasses and herbs (SPR).

Materials and methods

Grassland and forages

For this study three kinds of silage produced from the following three types of grassland were harvested:

1. Intensively managed grassland (IM). The silage was produced from the first cut of an intensively managed sward (monoculture of *Lolium perenne*) grown on a clay soil at Lelystad (52°5' N, 5°5' E) and harvested on 5 May 2000. The pasture had been fertilized on 22 March 2000 at a rate of 112 kg N ha^{-1}.
2. Species-poor grassland (SPP). The silage was produced from species-poor wet grassland dominated by the grasses *Holcus lanatus, Agrostis stolonifera, Alopecurus pratensis* and *Poa trivialis* and comparable with a MG13 community (Rodwell, 1993) or a sub-community of *Molinio arrhenatheretea* (Schaminée *et al.*, 1996). The pasture was managed to encourage nesting of meadow birds, and was fertilized on 10 March 2000 with cattle slurry at a rate of 20 m^3 ha^{-1}. It was situated in Spijkerboor (52°5' N, 5°0' E), on a peat soil. To enable birds to complete nesting, harvesting took place on 7 June 2000.
3. Species-rich grassland (SPR). The silage was produced from a species-rich sward consisting of a mixture of grasses and herbs, comparable with a MG1 community (Rodwell, 1993) or an *Arrhenatheretum eliatus* community (Schaminée *et al.*, 1996). The pasture was part of a nature reserve and had not been fertilized since about 1980. It was situated in Amerongen (52°0' N, 5°5' E) on a riverbank of clay.

To maintain biological diversity, harvesting did not take place until 21 June 2000. The harvested herbage was wilted (maximum wilting period < 72 h) to a dry matter (DM) content of 600–750 g kg^{-1} and was ensiled in bales.

Before harvesting, SPR and SPP were sampled to assess botanical composition. Sampling and analysis of the air-dry samples were carried out as described by De Vries & De Boer (1959). IM was not analysed for botanical composition. This pasture had been sown on 25 September 1998 with two cultivars of *Lolium perenne*: 50% cv. Pagode and 50% cv. Cambridge.

Experimental

The experiment was a completely randomized block design with 5 treatments and 6 replications. Thirty mid lactation multiparous dairy cows (days after calving 183 ± 14; lactation number 2.5 ± 0.4) were blocked (5 cows per block) in such a way that the pre-experimental calving date, milk yield (36.3 kg d^{-1} ± 1.8) and milk composition (fat content 4.0% ± 0.3; protein content 3.4% ± 0.1) within a block were comparable. Each cow within a block was randomly assigned to one of the 5 experimental treatments.

The experiment started on 31 July 2000 and lasted 10 weeks, including a 2-week adaptation period. The cows were housed in a free-range barn and offered a total mixed ration, using roughage intake control stations (RIC; Insentec, Marknesse, The Netherlands). The RIC station recorded the daily intake per cow. Intake was restricted, but not all cows reached the maximum intake. The cows could visit the RIC station throughout the day as often as they wanted, but when maximum intake of the mixed ration of a cow was attained, further access to the mixed ration was denied.

On a DM basis, the mixed ration consisted of 63% grass silage, 18% maize silage and 19% concentrates. The mixture was prepared daily in the morning and fed out on an average allowance of 19.7 kg DM per cow per day distributed over two meals, one directly after mixing and one in the afternoon. The feed residues of the previous day were removed in the morning before feeding.

The grass silage component of the mixed ration in the five experimental diets was as follows:

1. Silage from intensively managed grassland (100IM diet).
2. As sub 1 but IM silage for 20% replaced with silage from species-poor grassland (20SPP diet).
3. As sub 2 but 40% replacement instead of 20% (40SPP diet).
4. As sub 2 but 60% replacement instead of 20% (60SPP diet).
5. As sub 1 but IM silage for 60% replaced with silage from species-rich grassland (60SPR diet).

In addition to the mixed ration, cows were fed 0.43 kg DM concentrates per day in the milking parlour. The cows with the higher milk production levels also received extra concentrates in concentrate boxes, because it was calculated that these cows would not be able to maintain milk production if their mixed ration was not supplemented with extra concentrates. So the amount of extra concentrates offered depended on the energy requirements as calculated from the requirements for milk and maintenance of the cows (Van Es, 1978) on the 100IM diet. The amount of concentrates was the same for all cows of a block, and the concentrates fed via the concentrate boxes were similar to the concentrates fed in the mixed ration. Calculations furthermore indicated that on the 40SPP, 60SPP and 60SPR diets a protein deficiency could occur if concentrates with a regular protein content were used (Tamminga *et al.*, 1994). To prevent this, cows on the 40SPP, 60SPP and 60SPR diets received concentrates with 195 g true protein digested in the intestine (DVE) or 302 g CP per kg DM. On the other hand, the concentrates in the 100IM and 20SPP diets contained 147 g DVE or 236 g CP per kg DM. The composition of the two concentrates with different DVE content was kept as similar as possible (Table 1).

Measurements

Cows were milked twice a day (at 6:00 h and 15:00 h) and were weighed after milking, with milk yield and live weight being recorded automatically. Each week the average milk production per cow per day and the average weight per cow were calculated. In weeks 3 to 10, milk samples were taken from two consecutive milkings and analysed for fat, protein and lactose, which were determined by infrared analysis (Stichting Melkcontrolestation Nederland, Zutphen, The Netherlands).

In weeks 3 to 10, grabbed samples were taken from each grass-silage on five days each week before ration preparation. The daily samples were subsequently bulked for each 5-day period. The maize silage offered was sampled twice during the study (weeks 4 and 7), while a single sample of concentrates offered was taken in week 7. Maize silage and concentrates were produced in one big bunch, so their chemical composition was assumed to be consistent over the weeks. All samples were stored at –18 °C until analysis.

Grass silage samples were oven dried at 70 °C and analysed for DM, crude ash (ASH), nitrogen (Kjeldahl N), neutral detergent fibre (NDF) and sugars (SU), according to standard analytical procedures of the Animal Nutrition Group in Lelystad (Steg *et al.*, 1990). DM was determined at 103 °C, ASH at 550 °C, N was analysed by the Kjeldahl method, NDF according to Robertson & Van Soest (1981) and SU according to the method described by Van Vuuren *et al.* (1993). Crude protein (CP) was calculated as N x 6.25. *In vitro* organic matter digestibility (OMD) was determined according to the method of Tilley & Terry (1963), as modified by Van Der Meer (1986). The NDF and SU contents of the grass silage were only determined in weeks 3, 6 and 9.

The samples of maize silage and concentrates were analysed for DM, ASH, Kjeldahl N, NDF, *in vitro* digestibility (OMD) and starch. Methods of analysis were similar to those used for the grass silage.

Energy requirements of the dairy cows and the energy contents of the different feeds were calculated as net energy for lactation (NEL; Van Es, 1978; Anon., 2001a, b). The protein requirements and contents were calculated as DVE and degraded protein balance in the rumen (OEB), according to Tamminga *et al.* (1994). The structure index (SI) for grass silage was calculated according to Anon. (2001a, b), using the equation SI = 0.0065 x NDF – 0.20.

Table 1. Composition of the concentrates[1] used in the experiment.

Component	Concentrates 1	Concentrates 2
	--- (g per kg fresh product) ---	
Toasted lupine seeds	74	108
Extracted soya beans (type a)	50	84
Extracted rape seed	107	122
Condensed sugar beet molasses solubles	55	53
Premix minerals / vitamins	8	8
Chalk	9	4
NaCl	1	1
MgO	1	0
Citrus pulp	100	100
Coconut expeller	75	75
Maize gluten meal	100	100
Oil palm kernel expeller	200	10
Sugar beet pulp	50	50
Extracted linseed	100	100
Extracted soya beans (type b)	10	125
Sugar beet molasses	60	60

[1] Concentrates 1 contained 147 g DVE per kg (DVE = true protein digested in the intestine); concentrates 2 contained 195 g DVE per kg.

Table 2. Botanical composition of the species-poor (SPP) and the species-rich (SPR) grassland.

Botanical species	SPP	SPR	Botanical species	SPP	SPR
	(g per 100 g DW [1])			(g per 100 g DW)	
Grasses			Other herbs		
Agrostis stolonifera	12.3	3.3	*Achillea millefolium*	– [2]	3.3
Alopecurus geniculatus	13.3	– [2]	*Anthiscus sylvestris*	–	4.1
A. pratensis	–	3.8	*Cardamine pratensis*	–	0.3
Anthoxanthum odoratum	0.2	0.6	*Centaurea jacea*	–	2.8
Arrhenatherum elatius	–	13.2	*Cerastium fontanum*	0.2	0.5
Avenula pubescens	–	0.1	*Cirsium arvense*	–	3.6
Bromus hordeaceus	3.1	2.9	*Crepis biennis*	–	3.8
Dactylis glomerata	–	3.6	*Galium mollugo*	–	3.9
Elymus repens	2.8	2.9	*Geranium sp.*	–	0
Festuca pratens	0.5	0.3	*Glechoma hederacea*	–	0.1
F. rubra	–	3.1	*Heracleum sphondylium*	–	3.1
Glyceria fluitans	1.2	–	*Leucanthemum vulgare*	–	0
Holcus lanatus	35.5	2.0	*Ornithogalum umbellatum*	–	0.1
Lolium perenne	5.9	4.1	*Pimpinella major*	–	0.4
Poa annua	0.5	–	*Plantago lanceolata*	–	3.4
P. pratensis	–	0	*Prunella vulgaris*	–	0
P. trivialis	13.9	1.8	*Ranunculus acris*	0.2	3.9
Trisetum flavescens	–	0.7	*R. repens*	3.2	0.2
Unidentified rest	6.8	10.7	*Rhinanthus angustifolius*	–	0.7
Total Grasses	95.9	53.1	*Rumex acetosa*	0.4	0.2
			Stellaria media	0	–
Legumes			*Tanacetum vulgare*	–	0.8
Lathyrus pratensis	–	4.9	*Taraxacum officinale*	–	1.1
Trifolium dubium	–	0.6	Total Other herbs	4.1	36.3
T. pratense	–	2.9			
T. repens	0	1.7			
Vicia cracca	–	0.4			
Total Legumes	–	10.5			

[1] DW = dry weight.

[2] – = not determined.

Statistical analyses

The intake and production data of the cows were analysed with analysis of variance, using the statistical programme Genstat (Anon., 1993). For intake the model $Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij}$ was used, where μ = mean, α_i = effect of block i, β_j = effect of treatment j, and e_{ij} = residual error (within-blocks variation). For milk production characteristics and animal weight a covariate γx_{ij} (between blocks) was included in the model: $Y_{ij} = \mu + \alpha_i + \beta_j + \gamma x_{ij} + e_{ij}$. This covariate was based on measurements recorded during a 14-day period prior to the start of the experiment. Treatment means were differentiated with Student's t-test.

Results

Grassland composition

Visual assessment suggested the intensively managed grassland to consist mainly of *Lolium perenne*. On SPP, 12 grass species, 1 legume species and 5 species of other herbs were identified, representing 95.9, 0.03 and 4.05%, respectively, on air dry weight basis (Table 2). The dominant grass species was *Holcus lanatus*. On SPR, 15 grass species, 5 legume species and 22 species of other herbs were identified, representing 53.1, 10.5 and 36.3%, respectively, on air dry weight basis (Table 2).

Chemical composition and nutritive value of the silage components

Compared with the silage from intensively managed grassland, the CP content of the silage from species-poor grassland was lower, whereas the NDF content was higher (Table 3). Furthermore, this silage had a higher sugar content than the other forages (> 80 g kg^{-1}). Also the NEL content was lower.

Compared with the silage from IM, the CP content of the silage from SPR was lower and therefore also DVE and OEB were lower, whereas the NDF content was higher (not statistically), but lower than of the silage from SPP (not statistically). The NEL content was lower for the silage from SPR than for the silage from SPP or IM.

Feed intake

Replacing part of the silage from IM with silage from semi-natural grassland did not reduce total dry matter intake (DMI), except with the 60SPP diet (Table 4). Consequently, the NEL and DVE intake with the 60SPP diet was also significantly lower, but the DVE intake with the 60SPP and 60SPR diets was similar. Although DMI with the 60SPR diet was similar to DMI with the 100IM, 20SPP and 40SPP diets, DVE intake was lower with 60SPR than with the 100IM and 40SPP diets. The OEB intake was lowest, although still sufficient, with the 60SPR diet, which was caused by the low protein content of silage from SPR. The NDF intake per kg DM was lowest with the 60 SPR diet and the structure index was lowest with the 100IM and 60SPR diets (Table 4).

Table 3. Chemical composition and digestibility of the feeds offered.

Feed [1]	DM [2]	ASH	CP [3]	Sugars	Starch	NDF [4]	Structure index [5]	OM [6] digestibility	NEL [7]	DVE [8]	OEB [9]
	(g kg^{-1})	- - - - - - - - - - -	(g per kg DM)	- - - - - - - - - - - - -				(%)	(MJ per kg DM)	- (g per kg DM) -	
IM silage	601b [10]	107a	186a	58.5b	n.d.[11]	513b	3.14b	75.0a	6.0a	83.3a	35.5a
SPP silage	723a	95b	126b	90.7a	n.d.	575a	3.53a	59.1b	4.5b	51.2b	1.7b
SPR silage	589b	98b	101c	58.0b	n.d.	541ab	3.32ab	56.1c	4.2c	33.4c	−5.9c
SED [12]	11.8	3.5	2.5	8.4		15.9	0.103	0.89	0.07	1.64	2.3
Maize silage [13]	382	41	69	n.d.	333	337	1.33	77.5	6.9	48	−34
Concentrates											
– low in DVE [14]	883	93	236	113	58.1	343	0.27	82.0	7.3	147	30.1
– high in DVE [14]	874	91	302	129	69.7	264	0.22	84.8	7.4	195	51.5
– in milking parlour [14]	892	92	178	140	53.9	n.d.	0.26	n.d.	7.3	1170	

1 IM silage = silage from intensively managed grassland; SPP silage = silage from species-poor grassland; SPR silage = silage from species-rich grassland.

2 DM = dry matter.

3 CP = crude protein.

4 NDF = neutral detergent fibre.

5 Structure index according to Anon. (2001a, b).

6 OM = organic matter.

7 NEL = net energy for lactation (Van Es, 1978).

8 DVE = true protein digested in the small intestine.

9 OEB = degraded protein balance in the rumen (Tamminga *et al.*, 1994).

10 Means in the same column, followed by a different letter differ statistically ($P < 0.05$).

11 n.d. = not determined.

12 SED = standard error deviation.

13 Results based on two samples.

14 Results based on a single sample.

Table 4. Effect of diet on feed intake and feed quality. Cows were offered silage from intensively managed grassland (100IM) or a diet in which this silage was replaced for 20% (20SPP), 40% (40SPP) or 60% (60SPP) with silage from species-poor grassland, or with 60% (60SPR) from species-rich grassland.

	Diet					SED [1]
	100IM	20SPP	40SPP	60SPP	60SPR	
Dry matter intake (kg day^{-1} cow^{-1})						
Mixed ration:						
IM grassland	11.8	9.3	6.9	4.2	4.7	– [2]
SPP grassland	0	2.6	5.0	6.9	0	–
SPR grassland	0	0	0	0	7.0	–
Maize silage	3.4	3.4	3.3	3.1	3.5	–
Concentrates	3.7	3.7	3.5	3.3	3.7	–
Total mixed ration	19.0a [3]	19.0a	18.8a	17.6a	19.0a	0.45
Concentrates in boxes	2.0	2.0	2.0	2.0	2.0	–
Concentrates milking parlour	0.43	0.43	0.42	0.43	0.43	–
Total dry matter intake	21.4a	21.4a	21.2a	19.9b	21.3a	0.45
Feed quality						
NEL [4] (MJ day^{-1} cow^{-1})	140a	136ab	131bc	120d	128c	2.6
DVE [5] (g day^{-1} cow^{-1})	1884ab	1806bc	1939a	1769c	1771c	40
OEB [6] (g day^{-1} cow^{-1})	462a	379c	401b	306d	264e	9.8
Crude protein [7] (g per kg DM)	180b	173d	183a	177c	170e	1.2
NDF [8] (g per kg DM)	435b	444a	431c	438b	423d	1.2
Structure index [9]	2.022a	2.082b	2.098c	2.135d	2.030a	0.006

[1] SED = standard error deviation.
[2] – = not determined.
[3] Means in the same row, followed by a different letter are statistically different ($P < 0.05$).
[4] NEL = net energy for lactation (Van Es, 1978).
[5] DVE = true protein digested in small intestine.
[6] OEB = degraded protein balance in the rumen (Tamminga *et al.*, 1994).
[7] Average for total diet, including concentrates in boxes and milking parlour.
[8] NDF = neutral detergent fibre (average for total diet, including concentrates in boxes and milking parlour).
[9] According to Anon. (2001a, b).

Animal performance

The diets had no statistically significant effect on milk yield (Table 5), but milk composition and fat and protein yields were different amongst treatments. Consequently, also fat and protein corrected milk (FPCM) was different.

During the course of the experiment milk production gradually dropped. The decline was most rapid during the first weeks, and was more pronounced with the

Table 5. Effects of diet on milk output [1] and body weight. Cows were offered silage from intensively managed grassland (100IM) or a diet in which this silage had been replaced for 20% (20SPP), 40% (40SPP) or 60% (60SPP) with silage from species-poor grassland, or with 60% (60SPR) from species-rich grassland.

	Diet					SED [2]
	100IM	20SPP	40SPP	60SPP	60SPR	
Milk production (kg day^{-1} cow^{-1})	26.8	26.7	25.6	25.7	25.3	0.92
Fat content (%)	4.56a [3]	4.54a	4.43a	4.07b	4.43a	0.11
Protein content (%)	3.47a	3.51a	3.46a	3.49a	3.37	0.04
Milk fat yield (kg day^{-1} cow^{-1})	1.24a	1.21ab	1.12bc	1.04d	1.09cd	0.04
Milk protein yield (kg day^{-1} cow^{-1})	0.93a	0.93a	0.89ab	0.89ab	0.84b	0.03
FPCM [4] (kg day^{-1} cow^{-1})	29.0a	28.6ab	26.9bc	26.1c	26.2c	0.88
Mean weekly body weight (kg)	611	602	631	604	622	31.0
Body weight gain (kg in 8 weeks)	41	27	25	37	35	16.1

[1] Corrected for covariate.
[2] SED = standard error deviation.
[3] Means in the same row, followed by a different letter are statistically different ($P < 0.05$).
[4] FPCM = fat and protein corrected milk.

40SPP, 60SPP and 60SPR diets than with the 100IM and 20SPP diets (Figure 1). Milk fat and milk protein content increased during the trial. There was a tendency for a quicker decline in FPCM production with the 60SPP diet compared with the other diets, but this was not statistically significant. During the experiment the animals gained weight on all diets.

Discussion

Chemical composition

Generally, forage from pastures managed to encourage the nesting of meadow birds is expected to have a higher feeding value than forage from natural grassland managed with a floristic objective, due to more severe restrictions in management, such as date of harvesting and possibilities of fertilization on species-rich grassland. The experimental results confirmed this: the NEL was higher for the silage from SPP than from SPR. However, the forage from SPR used in this trial consisted partly of legumes and other dicots, which may have had a positive influence on intake and on degradation rate (Thomson *et al.*, 1985; Wilman *et al.*, 1997) and therefore on the cows' performance.

Although harvested earlier, silage produced from SPP had a higher NDF content than silage produced from SPR, which may be a reflection of the differences in botan-

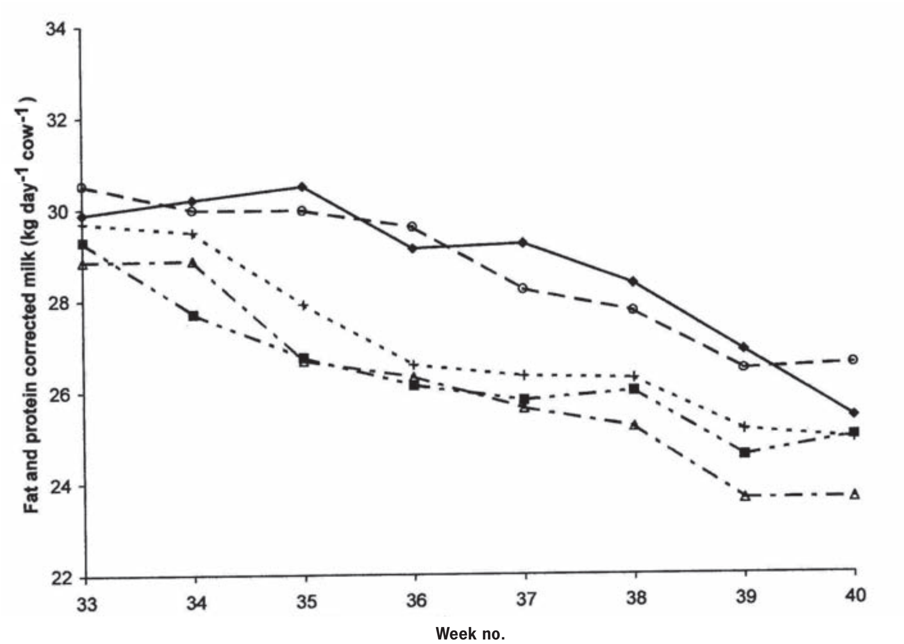

Figure 1. Fat and protein corrected milk yield during a feeding trial with cows fed diets containing silage from different origins. 100IM (◆): diet with silage from intensively managed grassland; 20SPP (o): diet in which 20% of the silage from intensively managed grassland was replaced with silage from species-poor grassland; 40SPP (+): diet in which 40% of the silage from intensively managed grassland was replaced with silage from species-poor grassland; 60 SPP (Δ): diet in which 60% of the silage from intensively managed grassland was replaced with silage from species-poor grassland; 60SPR (■): diet in which 60% of the silage from intensively managed grassland was replaced with silage from species-rich grassland.

ical composition. Forage from SPP mainly contained mature grass species with a high NDF content as opposed to forage from SPR, which contained more herbs with a lower NDF content. However, the OMD of silage from SPP was still higher than that from SPR. This is probably due to the lower NDF digestibility of SPR (Bruinenberg *et al.*, 2004a).

The CP content of the forages from semi-natural grassland was low. This is in agreement with the findings of Tallowin & Jefferson (1999), taking harvesting date into account. Not using inorganic fertilizer combined with the late harvesting date had led to a low CP content. Although the proportion of legumes in the forage from SPR was higher than that in the forage from SPP, the average CP content was lower. This can be attributed to the fact that the CP content of grasses and herbs occurring in the forage from SPR may be low compared with the CP content of the grasses occurring in the forage from SPP, due to the later harvesting date or to the fertilization of SPP.

The low CP content of the forages from semi-natural grassland makes supplementing the diet with protein-rich concentrates necessary, especially if such forage is fed in large amounts.

In our experiment only two types of forage from semi-natural grassland were used, both harvested at a specific time and at a specific location. Each of the grassland types had a specific botanical composition, so the question could be raised whether these grasslands are representative for semi-natural grassland. However, it is believed that the characteristics of the forages in this study at least give an indication of the possibility to include forage from semi-natural grassland in the diets of dairy cows.

Forage composition and voluntary intake

Intake was significantly higher with the 60SPR than with the 60SPP diet, although the percentage replacement was similar. With the 60SPP diet, the cows ingested on average 6.9 kg silage per day from semi-natural grassland (39% of the mixed ration), whereas this was 7.0 kg per day (37% of the mixed ration) with the 60SPR diet. The inclusion of silage from SPR did not result in a decline in DM intake, compared with the 100IM diet, whereas the inclusion of silage from SPP did. The higher intake with the 60SPR diet compared with the 60SPP diet can be attributed to the higher amount of legumes and other herbs in the silage from SPR. Some dicots have a high palatability and particles of dicots are generally more easily broken down in the rumen than particles of grasses (Thomson *et al.*, 1985; Derrick *et al.*, 1993, Bruinenberg *et al.*, 2004b), which has a positive influence on intake and digestion (Derrick *et al.*, 1993; Wilman *et al.*, 1997). So even with a high NDF content, some dicots may show a higher intake (e.g. Wilman *et al.*, 1997). In general, legumes have higher intakes than grasses, which is attributed to a lower cell wall content, a faster particle size reduction, a faster rate of OM removal from the rumen, and a higher protein content (Meijs, 1981; Ulyatt, 1981; Thomson *et al.*, 1985; Wilman *et al.*, 1997). Some herbs (e.g. *Cirsium arvense* and *Rumex acetosa*) may have a negative effect on intake (e.g. Derrick *et al.*, 1993) but due to the low abundance of these species in SPR, no effect on dry matter intake was observed.

The low dry matter intake with the 60SPP diet could partly be explained by the high frequency of the grass *Holcus lanatus* (35% of DM). This species' digestibility declines rapidly during maturation (Korevaar, 1986). In general, the effect of maturation on degradability is larger in grasses than in herbs (Peeters & Janssens, 1998). The proportion of grasses was higher in the silage from SPP (95%) than from SPR (50%).

Conrad *et al.* (1964) suggest a positive relationship between OMD and voluntary intake, although this relationship disappears above an OMD of 70%. In our trials, overall OMD for all treatments was higher than 70% and therefore, according to Conrad *et al.* (1964), no effect of OMD on voluntary intake would be expected. This was confirmed by our results obtained with the 100IM and the 60SPR diets from which cows consumed the same amount of DM in spite of the large difference in OMD: 77.3 and 70.8%, respectively. Forbes (1995) suggests that NDF degradation is a better predictor for intake than digestibility. However, *in situ* NDF degradation of SPR was lower than NDF degradation of SPP (Bruinenberg *et al.*, 2004b), whereas the intake of SPR was higher than that of SPP. So in this case, NDF degradation is not a good predictor for intake.

The DMI with the 100IM and 60SPR diets was the same. This was not expected because of differences in cell wall composition: the lignin content in SPR was much higher than in IM (56 vs. 14 g kg^{-1}; Bruinenberg *et al.*, 2004b).

The replacement of IM silage with SPP silage did not result in a linear decrease in DMI. Only 60% replacement reduced DMI significantly compared with the other diets. The reduction in feed intake observed for the 60SPP diet is probably related to the capacity of the rumen to degrade NDF (De Visser *et al.*, 1998). The NDF content of SPP was high, whereas the degradation rate of NDF was low (Bruinenberg *et al.*, 2004b). The clearance rate of the rumen was therefore also relatively low (Bruinenberg *et al.*, 2004c). Cows probably reduced intake because they could not increase their rumen content any further.

Production characteristics

Although a statistically significant reduction in NEL intake with the 100IM diet and with most of the other diets was observed (Table 4), milk yield was little affected (Table 5). The lowest NEL intake with the 60SPP diet did not correspond to the lowest milk yield.

Milk yield expressed per 100 MJ NEL intake was 19.1, 19.6, 19.5, 21.4 and 20.5 kg cow^{-1} day^{-1} for the 100IM, 20SPP, 40SPP, 60SPP and 60SPR diets, respectively. So it is surmised that replacing highly digestible by poorly digestible silage increased energy utilization of the diet in terms of milk production.

The effect of a somewhat lower milk yield (40SPP, 60SPP and 60SPR diets), milk fat (especially with the 60SPP diet) and milk protein content (especially with the 60SPR diet) resulted in a significantly lower FPCM production with these diets than with the 100IM and 20SPP diets. The lower milk fat content with the 60SPP diet was unexpected. For example, replacing highly digestible forage with poorly digestible forage normally results in a higher milk fat content (Conrad *et al.*, 1964; Miller, 1979). With a structure index (SI) of 2.1 and an SI requirement larger than 1.12 for cows producing 26 kg of milk per day (Anon., 2001a), the drop in milk fat content cannot be attributed to a deficiency in structural material. While the composition of long-chain fatty acids in the diet may influence milk fat content, the differences in composition of fatty acids were relatively small (Fievez *et al.*, 2002). So the decline in milk fat content with the 60SPP diet could not be explained by the results of our experiment.

With the 60SPR diet, milk protein declined compared with the other diets but the reduction was small (maximum difference 0.14%) and the level of milk production was relatively high with all diets. The latter is attributed to the fact that the cows were in an advanced stage of lactation. The relatively low milk protein content with the 60SPR diet could have been an indication of energy deficiency. However, NEL intake with the 60SPP diet was significantly lower than with 60SPR diet (Table 5) but milk protein content was not reduced. Because protein, DVE and OEB were offered in sufficient amounts for all diets, it is not expected that these parameters influenced milk yield or milk composition.

Milk production and fat content, and thus FPCM production, dropped with the higher replacement percentages compared with the diets with 0% and 20% replacement. This indicates that if the replacement of IM silage with silage from semi-natural grassland is too high (over 40%), FPCM production will decrease. With such high replacement percentages, the diet will also have to be supplemented with protein-rich concentrates to maintain animal performance. Lower replacement percentages offer more possibilities for inclusion in a dairy cow's diet than high ones. If used in low quantities (< 40%), silage from semi-natural grassland can be included in the diet of lactating dairy cows without reducing production.

Practical implications and conclusions

From these results it can be concluded that in a mixed diet containing 55% grass silage, replacing up to 40% of the IM silage with silage from semi-natural grassland had no influence on yield and composition of the milk from high yielding dairy cows. A higher replacement percentage influenced milk yield and composition negatively. Although both semi-natural grassland silages used in this trial were poorly digestible, the effects of including these forages in diets for dairy cows on feed intake and milk performance were different. However, based on the results presented, the overall conclusion is that there is scope for including forage from semi-natural grassland into the diets of dairy cows. This could have a positive impact on preserving or increasing the flora and fauna in the landscape.

Acknowledgements

The authors wish to thank Dr A.M. Van Vuuren of Animal Sciences Group, Lelystad, Dr H. Korevaar of Plant Research International, Wageningen, and Mr A. Steg for their critical reading of an earlier version of the manuscript.

References

Anonymous, 1993. Genstat 5 release 3. Reference Manual. Oxford University Press, Oxford.

Anonymous, 2001a. Feeding Table 2001. Centraal Veevoederbureau (CVB), Lelystad, 110 pp. (in Dutch)

Anonymous, 2001b. Manual for the Calculation of Roughage Feeding Values. Centraal Veevoederbureau (CVB), Lelystad, 153 pp. (in Dutch)

Bruinenberg, M.H., H. Valk, H. Korevaar & P.C. Struik, 2002. Factors affecting digestibility of temperate forages from semi-natural grasslands: a review. *Grass and Forage Science* 57: 292–301.

Bruinenberg, M.H., H. Valk & P.C. Struik, 2004a. The voluntary intake and in vivo digestibility of forages from semi-natural grasslands in dairy cows. *NJAS – Wageningen Journal of Life Sciences* 51: 219–235.

Bruinenberg, M.H., A.H. Van Gelder, P. Gonzalez Perez, V.A. Hindle & J.W. Cone, 2004b. Estimating rumen degradability of forages from semi-natural grasslands, using nylon bag and gas production techniques. *NJAS – Wageningen Journal of Life Sciences* 51: 351–368.

Bruinenberg, M.H., H. Valk, P.C. Struik & A.M. Van Vuuren, 2004c. Rumen fermentation and degradation characteristics of dairy cows fed on diets consisting of an intensively managed sward and silages from semi-natural grasslands. *Journal of Agricultural Science, Cambridge* 142: 219–235.

Conrad, H.R., A.D. Pratt & J.W. Hibbs, 1964. Regulation of feed intake in dairy cows. I. Change in importance of physical and physiological factors with increasing digestibility. *Journal of Dairy Science* 47: 54–62.

Derrick, R.W., G. Moseley & D. Wilman, 1993. Intake, by sheep, and digestibility of chickweed, dandelion, dock, ribwort and spurrey, compared with perennial ryegrass. *Journal of Agricultural Science, Cambridge* 120: 51–61.

De Visser, H., A. Klop, C.J. Van Der Koelen & A.M. Van Vuuren, 1998. Starch supplementation of grass harvested at two stages of maturity prior to ensiling: intake, digestion and degradability by dairy cows. *Journal of Dairy Science* 81: 2221–2227.

De Vries, D.M. & Th. De Boer, 1959. Methods used in botanical research in The Netherlands and their application. *Herbage Abstracts* 29: 1.

Fievez, V., B. Vlaeminck, K. Raes, T.T. Chow, S. De Smet, D. Demeyer & M. Bruinenberg, 2002. Dietary and milk fatty acid composition in relation to the use of forages from semi-natural grasslands. In: J.L. Durand, J.C. Emile, C. Huyghe & G. Lemaire (Eds), Multi-function Grasslands, Proceedings of the 19th General Meeting of the European Grassland Federation, 27–30 May 2002, La Rochelle, pp. 558–559.

Forbes, J.W., 1995. Voluntary Food Intake and Diet Selection in Farm Animals. CAB International, Wallingford, 532 pp.

Frame, J., 1990. Herbage productivity of a range of grass species in association with white clover. *Grass and Forage Science* 45: 57–64.

Korevaar, H., 1986. Production and feeding value of grass from grasslands with restrictions in use and in fertilization for nature conservation. PhD thesis Wageningen Agricultural University, Wageningen, 157 pp. (in Dutch)

Korevaar, H. & C. Van Der Wel, 1997. Botanical composition and its impact on digestibility, nutritive value and roughage intake. In: R.D. Sheldrick (Ed.), Grassland Management and the ESA's, Occasional Symposium of the British Grassland Society No 32, 23–25 September 1997, Reading, pp. 255–257.

Meijs, J.A.C., 1981. Herbage intake by dairy cows. PhD thesis Wageningen Agricultural University, Wageningen, 264 pp.

Miller, W.J., 1979. Dairy Cattle Feeding and Nutrition. Academic Press, New York, 411 pp.

Peeters, A. & F. Janssens, 1998. Species-rich grasslands: diagnostic, restoration and use in intensive livestock production systems. In: G. Nago & K. Peto (Eds), Proceedings of the 17th General Meeting of the European Grassland Federation, 18–21 May 1998, Debrecen Agricultural University, Debrecen, pp. 375–393.

Robertson, J.B. & P.J. Van Soest, 1981. The detergent system of analysis and its application to human foods. In: W.P.T. James & O. Theander (Eds), The analysis of dietary fibre in food, Marcel Dekker, New York, pp. 123–158.

Rodwell, J.S. (Ed.), 1993. British Plant Communities, Vol. 3. Grassland and Montane Communities. Cambridge University Press, Cambridge, 540 pp.

Schaminée, J.H.J., A.H.F. Stortelder & E.J. Weeda, 1996. The Vegetation of the Netherlands, part 3; Grasslands, Edges and Dry Heath. Opulus Press, Upsala, 356 pp. (in Dutch)

Steg, A., S.F. Spoelstra, J.M. Van Der Meer & V.A. Hindle. Digestibility of grass silage. *Netherlands Journal of Agricultural Science* 38: 407–422.

Tallowin, J.R.B. & R.G. Jefferson, 1999. Hay production from lowland semi-natural grasslands: a review of implications for ruminant livestock systems. *Grass and Forage Science* 54: 99–115.

Tamminga, S., W.M. Van Straalen, A.P.J. Subnel, R.G.M. Meijer, A. Steg, C.J.G. Wever & M.C. Blok, 1994. The Dutch protein evaluation system: the DVE/OEB system. *Livestock Production Science* 40: 139–155.

Thomson, D.J., D.E. Beever, M.J. Jhaines, S.B. Cammell, R.T. Evans, M.S. Dhanoa & A.R. Austin, 1985. Yield and composition of milk from Friesian cows grazing either perennial ryegrass or white clover in early lactation. *Journal of Dairy Research* 52: 17–31.

Tilley, J.M.A. & R.A. Terry, 1963. A two-stage technique for the in vitro digestion of forages crops. *Journal of the British Grassland Society* 18: 104–111.

Ulyatt, M.J., 1981. The feeding value of temperate pastures. In: F.H.W. Morley (Ed.), Grazing Animals. Elsevier, Amsterdam, pp. 125–141.

Van Der Meer, J.M., 1986. Optimal Prediction of In Vivo Organic Matter Digestibility for Ruminants by In Vitro Methods. Report No 177, Research Institute of Livestock Feeding and Nutrition, Lelystad, 11 pp.

Van Es, A.J.H., 1978. Feed evaluation of ruminants. I. The systems in use from May 1977 onwards in the Netherlands. *Livestock Production Science* 5: 331–345.

Van Vuuren, A.M., C.J. Van Der Koelen, H. Valk & H. De Visser, 1993. Effects of partial replacement of ryegrass by low protein feeds on rumen fermentation and nitrogen loss by dairy cows. *Journal of Dairy Science* 76: 2982–2993.

Wilman, D., R.W. Derrick & G. Moseley, 1997. Physical breakdown of chickweed, dandelion, ribwort, spurrey and perennial ryegrass when eaten by sheep and when macerated. *Journal of Agricultural Science, Cambridge* 129: 419–428.