Research Article

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Italian ryegrass silage in winter feeding of organic dairy cows: forage intake, milk yield and composition

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Abstract

BACKGROUND: Organic milk production aims at efficient use of home-grown feeds, especially forages, to minimise the quantity of purchased feeds. In conventional agriculture, Italian ryegrass (*Lolium multiflorum* Lam.) is known for its high energy content and palatability, and the aim of the present study was to examine its suitability as feed for organic dairy cows. Therefore a feeding trial was conducted comparing a diet including 50% (of silage dry matter (DM)) of Italian ryegrass silage with a control diet based on grass/clover silage (a mixture of the second cut from permanent grassland and the second cut from a perennial clovergrass ley) alone.

RESULTS: Inclusion of Italian ryegrass silage in the diet increased forage intake significantly (14.5 *vs* 13.4 kg DM in the control group) and concentrate intake did not differ, but milk yield was slightly lower (20.3 *vs* 21.0 kg) owing to the low energy and protein concentration of Italian ryegrass silage.

CONCLUSION: Italian ryegrass was indeed found to be highly palatable, confirming in principle its suitability as feed for organic dairy cows. However, higher energy and protein concentrations in this forage would be necessary to translate the high intakes of Italian ryegrass silage into improved milk production as well.

Keywords: organic; dairy cow; Italian ryegrass; nutrition

INTRODUCTION

Ruminant production plays a vital role in organic agriculture owing to ruminants' ability to utilise feed unsuitable for human consumption. Consequently, organic dairy cow nutrition strives to optimise the use of home-grown forages and to minimise the use of commercial concentrates.[1]

In conventional agriculture, Italian ryegrass (*Lolium multiflorum* Lam.) is widely known as a high-yielding, high-energy forage that is well suited for the feeding of dairy cows, last but not least because of its ability to promote high forage intakes.[2–5] In Austria, Italian ryegrass is rarely cultivated owing to its low frost resistance. A cultivation trial carried out in Switzerland showed lower yields for organically grown Italian ryegrass, but the best varieties performed well under both integrated and organic conditions.[6] Italian ryegrass swards establish quickly, the forage can be cut early and it is well suited for ensiling.[7,8] Hence it was hypothesised that ley farming of Italian ryegrass is feasible in organic agriculture as well.

To examine the suitability of Italian ryegrass silage for winter feeding of organic dairy cows, the forage was organically cultivated, ensiled and fed to dairy cows during a feeding trial. It was hypothesised that the high forage intakes of Italian ryegrass silage reported under conventional conditions could be confirmed for organic agriculture as well. Further hypotheses were that milk yield would be positively influenced by forage intake and that the quality of the produced milk would not change. Since feeding regimen is the main influence on milk fatty acid profile,[9] this variable was chosen for the further description of milk quality.

EXPERIMENTAL

Italian ryegrass harvest

The organic farm of the Secondary Agriculture and Forestry College at Ursprung (HLFS Ursprung) in the province of Salzburg, Austria (570 m Metres Above Sea Level (MASL), 1250 mm annual precipitation, 8.5 °C average annual temperature) was chosen as the site for the experiment. On 3 September 2007, Italian ryegrass (organic cultivar TEANNA) was sown, following spring grains and a mixture of catch crops. The first cut (13 May) in 2008 was a cleaning cut, while the second (20 June) and third (19 July) cuts were used for silage (round bales). From the fourth cut (27 August), hay was prepared using a ventilation system. After each cut, dairy manure was applied at a level of approximately 60 kg N ha^{-1}. For the chemical composition of Italian ryegrass silage, see Table 1.

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Table 1. Nutrient contents and fermentation traits of feeds (g kg^{-1} DM unless stated otherwise)

Item	Grass/clover silage	Clovergrass silage	Hay[a]	Italian ryegrass: Ensiled, 2nd cut	Italian ryegrass: Ensiled, 3rd cut	Italian ryegrass: Hay	Concentrate: Type 1	Concentrate: Type 2
Nutrients								
DM	269	194	947	471	355	947	929	939
Crude protein	119	163	130	85	118	109	150	312
uCP	123	137	127	120	126	121	163	218
Crude fat	31	40	26	26	36	25	52	96
NDF	568	506	620	574	557	572	–	–
ADF	404	392	385	364	363	343	–	–
ADL	68	70	68	50	47	47	–	–
Ash	114	120	79	78	98	102	61	78
NEL (MJ)	5.68	5.73	5.56	5.82	5.86	5.47	7.61	8.32
Fermentation traits								
pH	4.4	4.7	–	4.6	4.5	–	–	–
Lactic acid	72.2	59.3	–	19.3	57.2	–	–	–
Acetic acid	20.9	28.9	–	5.9	6.2	–	–	–
Butyric acid	0.1	10.4	–	4.6	16.8	–	–	–
Ammonia N (% of total N)	10.2	15.1	–	6.5	8.4	–	–	–

DM, dry matter (g kg^{-1} fresh weight); uCP, utilisable crude protein at the duodenum; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin; NEL, net energy for lactation.
[a] Derived from the 3rd cut of permanent grassland.

Experimental design and animals

The feeding experiment was conducted as a changeover design and took place between November 2008 and February 2009. Eleven multiparous and five primiparous Holstein cows were used, housed in a cubicle housing system with Calan gates for individual feeding. Cows were allotted to two treatment groups of eight cows each according to milk yield, days in milk and number of lactations. At the beginning of the data collection period (1 December 2008) the average ($\pm$ standard deviation) milk yield was 22.4 $\pm$ 5.6 kg day^{-1}, days in milk were 100 $\pm$ 59 and number of lactations was 3 $\pm$ 1.7. The experiment lasted for 14 weeks, with a 3 week period of adaptation to the Calan gates and the feeding regimen at the beginning and a changeover period of 2 weeks in weeks 10 and 11.

Feeding regimen

Two forage-based diets were compared in the experiment. The forage mixture in the control diet (C) was typical for winter feedings of organic dairy cows in Austrian organic agriculture. It consisted of the ensiled first cut of a perennial clovergrass ley and of grass/clover silage (second cut) derived from approximately 50% permanent grassland and 50% perennial clovergrass leys. The botanical composition of the permanent grassland was approximately 50% grasses (important species were *Dactylis glomerata* L., *Festuca pratensis* Huds., *Lolium perenne* L. and *L. multiflorum* Lam.), 20% legumes (important species were *Trifolium repens* L., *Trifolium pratense* L. and *Vicia sepium* L.) and 30% herbs (important species were *Taraxacum* sect. *Ruderalia, Plantago lanceolata* L., *Achillea millefolium* L., *Prunella vulgaris* L., *Ranunculus repens* L. and *Rumex obtusifolius* L.). The perennial clovergrass leys consisted of 31% *T. pratense* L., 9% *T. repens* L., 23% *L. perenne* L., 14% *D. glomerata* L., 9% *Phleum pratense* L. and 14% *F. pratensis* Huds.

In the forage mixture of the Italian ryegrass diet (RG), Italian ryegrass silage (second and third cuts) was substituted for 50% of silage dry matter (DM) in the control diet. Both forage mixtures included a small percentage of hay (third cut from permanent grassland in treatment C and fourth cut of Italian ryegrass in treatment RG) and were supplemented with the same two types of commercial concentrate to achieve isoenergetic and isonitrogenous total diets. Furthermore, 100 g of a commercial mineral and vitamin mixture was given to each cow daily. The chemical compositions and nutritional values of the feeds are listed in Table 1. Both diets were based on *ad libitum* allowance of forage mixtures, the compositions of which are summarised in Table 2. In both treatments, cows exceeding a daily milk yield of 14 kg received commercial concentrates at a rate of 1 kg DM per 2 kg additional milk yield, with a maximum of 8 kg DM concentrates day^{-1}, via an automatic feeding station. These quantities were adjusted weekly.

Data collection, analytical procedures and data calculation

Daily milk yield and concentrate intake were documented electronically throughout the experiment. Individual forage intake was recorded during four 6 day recording periods in weeks 3, 6, 9 and 11 of the trial using Calan gates. The forage mixtures were offered twice daily in amounts to ensure feed refusals of 5–10% of DM, which were weighed before the next feeding. The DM contents of both the fresh forage mixtures and the feed refusals were determined three times per recording period by oven drying at 105 °C for 32 h. In each recording period the following samples were taken for analysis of feed composition: one sample of each dietary component, three samples of the fresh forage mixtures and one sample of the feed refusals. Furthermore, one sample of each concentrate was taken every time the containers were refilled. The feed samples were analysed using methods described by ALVA[10] and VDLUFA.[11] Contents of utilisable crude protein at the duodenum (uCP)[12] were calculated according to GfE[13] (Table 3). Cows were milked twice daily at 06:00 and 16:30 in a herring milking parlour. Three individual milk samples were collected per recording period, each pooled

Table 2. Ingredients and nutrient contents of forage mixtures (g kg^{-1} DM unless stated otherwise)

	Forage mixture	
Item	C	RG
Ingredients		
Grass/clover silage	550	300
Clovergrass silage	400	220
Italian ryegrass silage, 2nd cut	–	180
Italian ryegrass silage, 3rd cut	–	240
Hay[a]	50	–
Italian ryegrass hay	–	60
Nutrients		
DM	315	350
Crude protein	132	114
uCP	130	124
Crude fat	33	30
NDF	535	559
ADF	387	388
ADL	67	63
Ash	113	108
NEL (MJ)	5.99	5.81

DM, dry matter (g kg^{-1} fresh weight); uCP, utilisable crude protein at the duodenum; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin; NEL, net energy for lactation.
[a] Derived from the 3rd cut of permanent grassland.

over two consecutive milkings. Between forage intake recording periods, milk samples were taken once a week. All individual milk samples were conserved with Bronopol and stored until analysis for fat, protein, lactose and urea concentrations. At each sampling date an additional set of milk samples was taken for analysis of fatty acid composition. Milk samples from all cows fed the same diet were pooled in proportion to provide one representative sample per treatment and sampling date. This second set of samples was stored at −20 °C until gas chromatographic analysis of fatty acid composition at the laboratory and quality service centre Muva Kempten, Germany. Cows were weighed immediately after milking twice per recording period. The methodology for computing nutrient balances and efficiency calculations according to GfE[13] is summarised in Table 3.

Statistical analysis

All data except the proportions of milk fatty acids were analysed using PROC MIXED from the statistical program package SAS.[14] The following model was used:

$$\begin{aligned} Y_{klmnopq} = \mu + \text{treatment}_k + \text{day}_l + \text{LS}_m + \text{milk}_n + {} & \\ \text{body weight}_o + \text{treatment} \times \text{LN} + {} & \\ \text{treatment} \times \text{LS} + \text{cow(order)}_{pq} + \varepsilon_{klmnopq} & \end{aligned}$$

where Y = variable studied on day l on cow p in treatment k with milk yield n, body weight o and in stage of lactation m; μ = overall mean; treatment = fixed effect of treatment k (C, RG); day = fixed effect of day l in the feeding trial (1, 2, . . ., 76); LS = fixed effect of stage of lactation m (1, 2, 3) (only for NDF intake, uCP balance and nitrogen efficiency); milk = continuous effect of daily milk yield n of cow p (only for intakes of concentrates, total DM, net energy for lactation (NEL) and uCP, and milk lactose content); body weight = continuous effect of body weight o of cow p (only for intakes of forage, total DM, NEL, protein and fibre fractions, and NEL balance; for milk protein content and fat and protein yield, body weight at the beginning of the feeding trial was used); treatment × LN = interaction between treatment k and lactation number s (only for milk yield, milk protein yield, NEL balance, milk from forage and concentrates kg^{-1} milk); treatment × LS = interaction between treatment k and stage of lactation m (only for NDF intake, nutrient balances, milk from forage and nitrogen efficiency); cow(order) = random effect of cow p within order q; ε = random error

Owing to lack of significance, the fixed effects order q (O_q) and lactation number r (LN_r) were excluded from the model. Only parameters that were statistically significant were included in the final reduced model. The seven covariance structures tested were unstructured (UN), antedependence (ANTE(1)), compound symmetry (CS), heterogeneous compound symmetry (CSH), spatial power law (SP(POW)), spatial gaussian (SP(GAU)) and spatial spherical (SP(SPH)). The covariance structure with the Akaike's information criterion value closest to zero was selected.

Analysis of variance for proportions of milk fatty acids was conducted using PROC GLM from the statistical program package

Table 3. Methodology of data calculation according to GfE[13]

Item	Calculation
uCP	{11.93 − [6.82 × (UDP/CP)]} × ME + 1.03 × UDP
uCP balance (%)	(uCP intake/uCP requirements for maintenance and milk production) × 100
uCP requirements for maintenance (g)	{[5.9206 × log(body weight) − 6.76 + 2.19 × kg DMI + 0.018 × (body weight)$^{0.75}$] × 6.25} × 2.1 (endogenous urinary and faecal N losses + N losses via skin)
uCP requirements for milk production (g)	(Daily milk yield × milk protein content) × 2.1
NEL balance (%)	(NEL intake/NEL requirements for maintenance and milk production) × 100
NEL requirements for maintenance (MJ)	0.293 × (body weight)$^{0.75}$
NEL requirements for milk production (MJ)	Daily milk yield × (0.38 × milk fat % + 0.21× milk protein % + 0.95)
Milk from forage (%)	[(NEL intake from forage − NEL requirements for maintenance)/NEL requirements kg^{-1} milk] × (100/daily milk yield)
Milk N as % of N intake	{[(Daily milk yield × milk protein content)/6.25]/(daily CP intake/6.25)} × 100

UCP, utilisable crude protein at the duodenum; UDP, ruminally undegradable feed protein; ME, metabolisable energy; DMI, dry matter intake; NEL, net energy for lactation.

SAS.[14] The model included the fixed effects treatment, order and day.

The tables give the least squares means for treatment, followed by residual standard deviation (SD) and probability (*P*) values together with the covariance structure (CovS) used. Statistical differences were considered to be significant when $P < 0.05$.

RESULTS

Feed composition

Table 1 shows the mean chemical compositions of the different forages and commercial concentrates. Table 2 gives the compositions of the forage mixtures. These data were not subjected to statistical analysis.

Although there was a large variation in DM between the different forages, the difference in DM of the forage mixtures was only 35 g. Feeds produced from Italian ryegrass had lower crude protein contents than feeds from grass/clover mixtures. Accordingly, the forage mixture of treatment RG had a lower crude protein but also a lower energy content than the control forage mixture. Grass/clover silage and the ensiled third cut of Italian ryegrass had almost the same crude protein and roughly comparable DM content, but their contents of fibre fractions differed. While Italian ryegrass silage (third cut) contained approximately the same amount of neutral detergent fibre (NDF) as grass/clover silage, its acid detergent fibre (ADF) and acid detergent lignin (ADL) contents were distinctly lower, with ADF making up 65% and ADL 8% of total NDF, compared with 71 and 12% of total NDF in grass/clover silage. This difference in fibre fractions had practically no effect on the forage mixtures, which had almost identical ADF and ADL contents. However, NDF content of the Italian ryegrass forage mixture was 4% higher than NDF content of the control forage mixture.

Feed and nutrient intake

DM intake, nutrients and energy are presented in Table 4.

In treatment RG, forage intake was significantly increased by 8% as compared with treatment C. Concentrate intake was numerically lower in treatment RG than in treatment C, but the differences were not statistically significant. Consequently, total DM intake of cows offered the Italian ryegrass diet was significantly higher as well. There was a significant but small effect of treatment on total energy intake, with cows in treatment RG consuming more total energy (+2%) than cows in treatment C. No difference was observed for intakes of crude fat and crude protein, whereas intake of uCP was significantly higher for cows offered the Italian ryegrass diet than for cows offered the control diet. The above-mentioned comparatively higher forage intake of cows in treatment RG was associated with higher intakes of fibre fractions. NDF intake in particular showed a significant interaction between treatment and stage of lactation. Even so, a positive effect of treatment RG on NDF intake could be observed for cows in every stage of lactation, averaging +15%. Likewise, treatment RG significantly increased ADF intake by 9% and ADL intake by 3%.

Milk yield and composition

The effects of dietary treatment on milk yield and composition are shown in Table 5.

For milk yield a significant interaction between treatment and lactation number was observed. Both primiparous and older cows (in their fourth or higher lactation) had lower milk yields when consuming the Italian ryegrass diet (-5 and -6% respectively) as compared with cows fed the control diet, whereas cows in their third lactation showed a slightly positive response (+3%). On average, treatment RG led to a lower milk yield (−3%) than treatment C.

Treatment affected neither milk fat content nor fat yield. No effect on protein content was found either, but protein yield showed a significant interaction between treatment and lactation number. Only cows in their third lactation had slightly higher protein yields when fed the Italian ryegrass diet (+6%), whereas all others showed lower protein yields compared with cows fed the control diet. On average, treatment RG decreased protein yield slightly (−1%). Lactose content of milk did not differ between treatments, while urea content was significantly lower (−7%) in milk from cows consuming the Italian ryegrass diet as compared with cows fed the control diet.

Table 4. Daily intake of dry matter, nutrients and energy

	Treatment			*P* value[a]			
Item	C	RG	SD	T	T × LN	T × LS	CovS[b]
Dry matter (kg)							
Forage	13.4	14.5	1.32	**<0.001**	–	–	SP(POW)
Concentrate	3.7	3.5	2.79	0.202	–	–	SP(SPH)
Total	17.1	17.9	1.36	**<0.001**	–	–	SP(POW)
Nutrients (g)							
Crude fat	699	703	56.6	0.628	–	–	SP(POW)
Crude protein	2569	2511	192	0.056	–	–	SP(POW)
uCP	2420	2474	176.9	**0.037**	–	–	SP(POW)
NDF from forage	7089	8200	684.3	**<0.001**	–	**0.012**	SP(POW)
ADF from forage	5144	5624	519.5	**<0.001**	–	–	SP(POW)
ADL from forage	887	919	87.8	**0.016**	–	–	SP(POW)
Energy (MJ NEL)	110	112	8.2	**0.030**	–	–	SP(POW)

[a] T, treatment; T × LN, interaction between treatment and lactation number; T × LS, interaction between treatment and stage of lactation, expressed as thirds (1st and 2nd 100 days, >200 days in milk).
[b] Covariance structure: SP(POW), spatial power law; SP(SPH), spatial spherical.

Table 5. Milk production traits, nutrient balances and efficiency of milk production

Item	Treatment C	RG	SD	*P* value[a] T	T × LN	T × LS	CovS[b]
Milk production							
Milk yield (kg)	21.0	20.3	1.46	**0.003**	<**0.001**	–	SP(POW)
Fat content (g kg^{-1})	37.7	37.9	2.99	0.429	–	–	CS
Protein content (g kg^{-1})	29.6	30.5	2.78	0.084	–	–	SP(SPH)
Lactose content (g kg^{-1})	47.7	47.1	2.75	0.267	–	–	SP(SPH)
Urea content (mg L^{-1})	199	185	35.0	**0.011**	–	–	SP(POW)
Fat yield (g)	770	778	336.8	0.913	–	–	SP(SPH)
Protein yield (g)	629	623	47.8	0.312	**0.008**	–	CS
Nutrient balances (%)							
NEL balance	107	113	8.7	<**0.001**	**0.013**	**0.002**	SP(POW)
uCP balance	122	126	7.6	<**0.001**	–	<**0.001**	SP(POW)
Efficiency of milk production							
Feed efficiency (kg milk kg^{-1} DMI)	1.24	1.13	0.12	<**0.001**	**0.012**	–	CS
Concentrates kg^{-1} milk (g DM)	152	131	31.65	**0.001**	**0.006**	–	SP(POW)
Milk from forage(%)	67.8	78.3	11.76	<**0.001**	**0.003**	**0.044**	SP(POW)
Milk N as % of N intake	24.7	24.6	5.04	0.929	–	**0.001**	SP(POW)

[a] T, treatment; T × LN, interaction between treatment and lactation number; T × LS, interaction between treatment and stage of lactation, expressed as thirds (1st and 2nd 100 days, >200 days in milk).
[b] Covariance structure: CS, compound symmetry; SP(POW), spatial power law; SP(SPH), spatial spherical.

Although treatment did not show an effect on the fat content of the cows' milk, it did influence the milk fatty acid profile, as summarised in Table 6. For the principal milk fatty acids C16 : 0, C18 : 0 and C18 : 1 c9, which together comprised approximately 600 g kg^{-1} total fat, no difference between the treatments could be found. However, treatment RG did lead to a significant increase in the proportions of short- and medium-chain fatty acids (C4 : 0 to C14 : 0) in milk fat as compared with treatment C. On the other hand, cows consuming the Italian ryegrass diet produced milk with significantly lower proportions of the unsaturated long-chain fatty acids C18 : 1 t11, C18 : 2 c9c12, C18 : 2 c9t11, C18 : 3 c9c12c15 and C18 : 3 c6c9c12 compared with cows fed the control diet. Inclusion of Italian ryegrass silage in the diet therefore resulted in significant increases in saturated fatty acids (SFA) and decreases in mono- and polyunsaturated fatty acids (MUFA and PUFA). Both the proportions of n-3 and n-6 fatty acids were significantly lower in treatment RG than in treatment C, whereas the ratio of n-6/n-3 fatty acids was significantly lower in treatment C.

Nutrient balances and efficiency of milk production

Nutrient balances and efficiency calculations are given in Table 5. Balances of NEL and uCP were positive for both treatments, and both balances were on average higher for cows offered the Italian ryegrass diet compared with cows consuming the control diet. NEL balance showed a significant interaction between treatment and lactation number, but treatment RG led to an increase in NEL balance in every lactation as compared with treatment C. For both NEL balance and uCP balance a significant interaction between treatment and stage of lactation was found. Cows in the first and last third of their lactations had higher balances in treatment RG than in treatment C, whereas cows in the middle third of their lactations had slightly lower balances.

Treatment RG decreased feed efficiency on average by 9% in comparison with treatment C, and although a significant interaction between treatment and lactation number was observed,

Table 6. Fatty acid profile and groups of fatty acids of milk fat (g kg^{-1} total fat)

Item	Treatment C	RG	SD	*P* value
Fatty acids				
C4 : 0	41.7	42.7	0.93	**0.003**
C6 : 0	23.0	23.7	0.64	**0.008**
C8 : 0	12.5	13.0	0.38	**0.001**
C10 : 0	25.0	26.2	0.84	**0.001**
C12 : 0	27.3	28.8	0.93	<**0.001**
C14 : 0	104	106	2.2	**0.003**
C16 : 0	267	268	7.2	0.896
C18 : 0	112	113	3.6	0.453
C18 : 1 c9	220	215	7.4	0.059
C18 : 1 t11	26.6	25.0	0.98	<**0.001**
C18 : 2 c9c12	17.0	16.4	0.53	**0.004**
C18 : 2 c9t11	10.2	9.7	0.50	**0.009**
C18 : 3 c9c12c15	7.8	6.9	0.34	<**0.001**
C18 : 3 c6c9c12	0.19	0.12	0.051	**0.001**
Fatty acid groups[a]				
SFA	636	645	9.6	**0.019**
MUFA	261	256	7.9	0.106
PUFA	28.9	27.3	0.81	<**0.001**
n-3 fatty acids	10.0	9.2	0.38	<**0.001**
n-6 fatty acids	18.9	18.1	0.56	**0.001**
n-6/n-3 ratio	1.89	1.98	0.071	**0.001**

[a] SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

this negative effect was found in every lactation. In comparison with cows offered the control diet, cows fed the Italian ryegrass diet consumed less concentrates kg^{-1} milk and produced more (+15%) milk from forage. Even though several significant interactions were observed for both traits, the mentioned effects were found for cows in every stage and lactation number. A significant interaction between treatment and stage of lactation was observed for the variable calculated efficiency of dietary nitrogen utilisation. Cows in the first and last third of their lactations showed a lower nitrogen efficiency when given the Italian ryegrass diet compared with cows fed the control diet, whereas cows in the middle third of their lactations showed a positive response. On average, treatment RG decreased nitrogen efficiency slightly (−0.4%).

DISCUSSION

This study is the first to examine the suitability of silage made from organically cultivated Italian ryegrass for the feeding of organic dairy cows. Two forage-based diets were compared, one of which (RG) included Italian ryegrass silage. Different proportions of two types of commercial concentrate were used to achieve isoenergetic and isonitrogenic total diets.

Feed composition

The crude protein and energy contents of grass/clover silage were unusually low (see Table 1), probably owing to a late cutting date caused by unfavourable weather.

Compared with the standard value of 137 g crude protein kg^{-1} DM that DLG[15] gives for silage from first-cut Italian ryegrass in full ear emergence, the crude protein contents of both ensiled cuts of Italian ryegrass in the present experiment (85 and 118 g kg^{-1} DM respectively) can be considered rather low. However, crude protein contents as low as 100 g kg^{-1} DM and even lower have frequently been reported, both for silage produced from Italian ryegrass mown at a late vegetative stage (58–99 kg^{-1} DM)[2,3] and for fresh Italian ryegrass before ear emergence, when high biomass yields could be achieved.[16] The difference in crude protein content between the second and the third cut of the present experiment might be related to the difference in regrowth period (38 and 29 days respectively), which was associated with different yields (1.4 and 0.9 t DM ha^{-1} respectively, data not shown), as well. The energy contents of Italian ryegrass silages (5.82–5.86 MJ NEL kg^{-1} DM) were below expectations, based on standard values given by DLG[15] (6.56 MJ NEL kg^{-1} DM) and previous studies under practically relevant conditions that reported energy values of 6.0 MJ NEL kg^{-1} DM and more.[8,16] Regarding the fibre carbohydrate composition, the Italian ryegrass silages in the present experiment contained lower proportions of ADF and ADL than mixed grass/clover silages. These results are in agreement with earlier studies by Tamburini *et al*.[17] and Crovetto *et al*.,[18] who observed similar and even more pronounced relations in the fibre carbohydrate compositions of Italian ryegrass.

The quality of the experimental silages with regard to pH value, acid content and ammonia N ranged from fair to very good, following the guidelines for quality assessment of silages proposed by Buchgraber and Gindl.[19] The ensiled second and third cuts of Italian ryegrass combined yielded approximately 2.3 t DM ha^{-1} (data not shown), which was well below the projected yield. Expectations were based on previous work by Suter *et al*.,[6] who documented Italian ryegrass yields of 3.1–8.4 t DM ha^{-1} $year^{-1}$ under organic agriculture conditions as compared with integrated farming (6.2–12.7 t DM ha^{-1} $year^{-1}$). The low yield in the present experiment may have resulted partly from the used cultivar TEANNA, which was developed in Italy and might therefore have been poorly adapted to the conditions in the Austrian province of Salzburg. TEANNA was chosen because it was the only variety available of organic quality.

Feed and nutrient intake

The general level of DM intake (DMI) observed in this experiment (13.4–14.5 kg of forage DM plus 3.5–3.7 kg of concentrate DM; see Table 4) is in accordance with the findings of Bruinenberg *et al*.,[20] who fed silage from both extensively and intensively managed grassland to dairy cows, supplemented with 4.5 kg of concentrates, and observed forage intakes of 13.2 and 13.9 kg DM respectively. Diet-related factors such as amount of concentrates and quality of forage account for half of the influences on DMI of dairy cows, the other half being animal-related factors.[21] Since concentrate intake did not differ between the treatments, the considerably higher forage intake of cows in treatment RG can be ascribed to the inclusion of Italian ryegrass silage. The superiority of the Italian ryegrass diet is even more noteworthy since the control diet was superior in regard to energy and protein content and therefore should have promoted higher intakes.[21] Previous studies under conventional agriculture conditions associated with high proportions of concentrates (45% of total diet DM) have shown higher intakes of Italian ryegrass silage as compared with corn silage and whole-crop cereal silages.[2,3] When concentrates were increased to 55% of the total diet DM, no difference in forage intake between Italian ryegrass silage and whole-crop wheat silage was observed.[4]

The positive but differing effect of treatment RG on intake of fibre fractions can be explained by the differences in the contents of fibre fractions observed in Italian ryegrass silage. Intake of NDF was considerably higher for cows in treatment RG, whereas the difference in ADF intake was already less pronounced and the difference in ADL intake only slight. Tamburini *et al*.[17] estimated *in situ* rumen degradability of Italian ryegrass and winter cereal silages with fistulated dry cows and found that Italian ryegrass had the highest degradation rate and effective degradability of NDF and ADF, which led to the conclusion that it can permit high feed intakes in lactating cows. Although not assessed in the present experiment, it can be assumed that the Italian ryegrasss forage mixture indeed contained a lower portion of ruminally undegradable and a higher portion of ruminally degradable fibre fractions, which could explain part of the higher forage intake.

The fact that the treatment significantly changed total energy intake indicates that the intention to have each diet supply equal amounts of energy was not fully met. This is thought to be due to the higher forage intake of cows in treatment RG, which also evened out the disadvantages of the Italian ryegrass diet with regard to energy and protein content.

Milk yield and composition

On average, treatment RG reduced milk yield, whereby the reduction was mainly observed in cows in their fourth and higher lactations (−6.7% or −1.7 kg). The difficulty to prove the effect of treatment on milk yield for all cows could be due to the limited number of cows available for this feeding trial. The general level of milk yield (20.3–21.0 kg) observed in this experiment is in agreement with earlier studies, reporting comparable intakes of forage (mainly grass silage) and concentrates and observing milk yields of 19.7–23.5 kg.[22,23] When feeding Italian ryegrass silage as the sole forage in diets high in concentrates (45–50% of total diet DM), milk yields of 28.1 kg[2] and 30.3 kg[5] respectively were reported. In comparison with corn silage, Bernard *et al*.[2] found significantly higher milk yields in cows fed Italian ryegrass silage, whereas Cooke *et al*.[5] found no difference in milk yield when feeding a forage base of 100% Italian ryegrass silage as compared with a mixture of silages from Italian ryegrass and corn.

Of milk components, only urea content was significantly affected by treatment, but the rather small difference (6 mg L^{-1}) does not seem practically relevant. Milk urea content is an indicator of the supply of nitrogen and energy for ruminal microbes and is assumed to be adequate when urea content is between 150 and 300 mg L^{-1} milk.[24] The average milk urea contents were within the desired range in both treatments. The general levels of protein and fat contents and yields recorded in this experiment are comparable to earlier feeding trials with organic dairy cows by Velik *et al*.[22] and Steinshamn and Thuen.[25]

Regarding the fatty acid composition of the produced milk, treatment RG increased the proportion of both short-chain SFA (up to eight carbon atoms) and medium-chain SFA (10–14 carbon atoms) but decreased unsaturated long-chain fatty acids. Since intake of concentrates and fat did not differ between treatments, this effect can be attributed to the inclusion of Italian ryegrass silage, which resulted in a diet lower in legumes and herbs than the control diet. Although there is general agreement on the fact that milk fatty acid composition is mainly determined by feed composition,[9] the literature does not give a consistent picture of the effect of feeding legumes in comparison with grass. Higher proportions of SFA and lower proportions of MUFA and PUFA in milk fat have been reported when feeding grass silage as compared with grass/clover silage (red and white clover)[26] and also when comparing permanent grassland with temporary grassland that was higher in legumes,[27] which is in accordance with the findings in the present experiment. In contrast, van Dorland *et al*.[28] observed lower proportions of short-chain SFA and higher proportions of MUFA in milk fat from cows fed grass silage in comparison with grass/clover silages (red and white clover). When comparing Italian ryegrass silage and whole-crop cereal silages, Cabrita *et al*.[3] recorded higher levels of short-chain SFA for the Italian ryegrass treatment but also higher proportions of the unsaturated long-chain fatty acids C18 : 2 and C18 : 3. The n-6/n-3 fatty acid ratio in treatment RG was significantly higher than in treatment C. Nevertheless, with ratios below 2 : 1, milk fat from all cows was well below the recommendation of 5 : 1 given by DACH[29] for human nutrition.

Nutrient balances and efficiency of milk production

The comparatively higher forage intake in treatment RG had a marked influence on the nutrient balances and all parameters of milk production efficiency except nitrogen utilisation (milk N as % of N intake).

To begin with, both NEL and uCP balances were higher on average for cows fed the Italian ryegrass diet. Why treatment RG failed to consequently promote higher milk yields is unclear, although a potential influence of body weight change cannot be completely ruled out, since requirements for changes in body tissues were not taken into account. As another consequence of the difference in forage intake, combined with only slightly differing milk yields, feed efficiency in treatment RG (1.13 kg milk kg^{-1} DMI) was lower than in treatment C (1.24 kg milk kg^{-1} DMI). These levels are somewhat low as compared with earlier studies reporting values of 1.34–1.40 kg milk kg^{-1} DMI for organic dairy cows fed grass/clover silages without and with supplementation (6.5 kg of cereals) respectively.[25,30] For diets consisting of 50% Italian ryegrass silage and 50% concentrates, feed efficiency levels as high as 1.51 kg milk kg^{-1} DMI have been reported.[5] Finally, cows in treatment RG consumed less concentrates kg^{-1} milk and produced more milk from forage. Although these effects indicate a superiority of the Italian ryegrass diet, they are put into perspective by the fact that total intake of concentrates did not differ and that milk yield differed only slightly between treatments. The level of estimated milk from forage reached in treatment RG (78.3%) is still lower than the 85% level that Weller and Bowling[1] observed for a sustainable organic milk production system.

The lack of treatment effect on efficiency of nitrogen utilisation can be explained by the similar crude protein intakes and protein yields of both treatments. Although a slightly negative effect of treatment RG was found for both primiparous and older cows (in their fourth or higher lactation), the extent of the decrease (0.8 and 0.6% points respectively) does not seem practically relevant. The general level of nitrogen efficiency found in the present experiment (24.6–24.7%) is in accordance with values calculated for organic dairy cows fed clovergrass silage and whole-crop cereal silages, supplemented with either barley or rape seed cake,[31] but lower than the mean (27%) for milk production systems with low nitrogen input given by Castillo *et al*.[32]

CONCLUSIONS

The most obvious effect found in this study was the markedly higher forage intake of organic dairy cows when Italian ryegrass silage was substituted for 50% of the silage DM in a diet based on grass/clover silage, which confirms previous work on conventionally cultivated Italian ryegrass. Unfortunately, the higher forage intake did not translate into improved milk yield owing to the inferior energy and protein concentrations of Italian ryegrass silage. Inclusion of Italian ryegrass silage in the diet adversely affected the fatty acid profile of milk; however, the overall levels were still decidedly favourable for human consumption. Italian ryegrass was found to be a highly palatable and therefore promising forage, but the low energy and protein values achieved in this first vegetative period might have undermined potential positive influences on milk production. If better qualities could be obtained, there is reason to assume that Italian ryegrass silage could contribute to sustainable organic milk production based on high milk yield from forage.

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