Journal of the Science of Food and Agriculture *J Sci Food Agric* **87**:2657–2664 (2007)

Effects of partial substitution of concentrates with maize silage in organic dairy cow rations on performance and feed efficiency†

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Abstract

BACKGROUND: The general goal of organic dairy farming is to minimize purchased concentrate use and focus on milk production from forages. The aim of the present paper is to examine the influence of a partial substitution of purchased concentrates with home-grown maize silage on feed intake, milk production and feed efficiency in rations for organic dairy cows. In the experimental treatment group (E), two-thirds of average herd concentrate intake was replaced with 2.7 kg maize silage on a dry matter (DM) basis.

RESULTS: In treatment E, total DM, energy and protein intake were significantly reduced compared to the control treatment group (C). Daily milk yield decreased in E by 11% and milk urea content was significantly lower. Calculated milk production from forage was significantly higher (91 *versus* 71%) in treatment E. Efficiency of dietary nitrogen (N) utilization (calculated as milk N as a percentage of N intake) was slightly improved in E and protein and energy balance (calculated as intake as a percentage of requirements) were closer to zero than in C.

CONCLUSION: The present study indicates a potential to reduce levels of concentrates and substitute them with maize silage in organic dairy cow rations at least in the second half of lactation.

Keywords: organic farming; dairy cow; protein; maize silage; milk production; feed efficiency

INTRODUCTION

Organic farming aims to reach a high level of self-sufficiency and to use its natural resources sustainably and efficiently. However, on many organic dairy farms, high amounts of external inputs are purchased in the form of concentrates, which must be viewed critically with regard to the following aspects: cost and availability of organically produced concentrates, forage utilization, intact nutrient cycles, use of fossil energy and the use of potential human food in animal feeding. Hence important goals in organic farming seem to be reducing concentrate use and maximizing the use of forages as well as increasing feed efficiencies.[1] Furthermore, organic field studies indicate that the protein and/or energy supply of organic dairy cows is often inadequate.[2–5]

According to European and Austrian regulations, on organic farms 60% of the daily ruminant diet has to consist of forages.[6,7] Hence grasslands are key components of organic dairy systems,[1] especially in countries like Austria, where 56% of the agricultural area is permanent grassland.[8] In organic dairy farming, but also in conventional low-input systems, grass and legume forages, which are important for nitrogen fixation and soil fertility, represent the main protein sources for dairy cows.

In these feedstuffs and their ensiled conserves, ruminal protein degradation occurs more rapidly than carbohydrate degradation.[9,10] If ruminally degradable feed protein and energy in the form of readily fermentable carbohydrates are not available in the rumen at the same time, high amounts of nitrogen cannot be utilized and must be excreted through urine and milk.[11] Therefore, several researchers have suggested supplementing grass–legume silage-based diets with maize silage, which is high in ruminally fermentable carbohydrates and low in protein.[12–15] Recent research shows that maize silage is also under organic farming conditions a reliable forage supplement that can be grown in most grassland regions of moderate altitude, and

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†Presented in part at the European Joint Organic Congress of Organic Farming and European Rural Development, Odense, Denmark, 30-31 May 2006

Contract/grant sponsor: Federal Ministry of Agriculture and Forestry, Environment and Water Management, Austria
(*Received 13 October 2006; revised version received 15 April 2007; accepted 16 May 2007*)
Published online 11 September 2007; DOI: 10.1002/jsfa.3028

that the production costs for maize silage are only slightly higher than those for clover–grass silages.[16] Furthermore, Sniffen *et al.*[9] reported that starch from ensiled grains is rapidly digested in the rumen, but dried grains contain high amounts of insoluble starch, which is digested slowly. Therefore, although not measured in the present study, it was hypothesized that maize silage instead of cereal grains could improve ruminal energy supply and nitrogen capture.

The purpose of the following work was to examine the effects of home-grown maize silage as a partial substitute for purchased concentrates on feed intake, energy and protein supply, milk performance and feed efficiency in rations for organic dairy cows. It was hypothesized that inclusion of moderate amounts of maize silage instead of concentrates in the diet would increase nitrogen efficiency and would not decrease daily milk yield by more than 5%.

Table 1. Chemical composition and calculated nutritive values of feeds (g kg^{-1} DM unless stated)

Component	Grass–clover silage	Hay	Maize silage	Concentrate
Dry matter	293	896	359	883
Crude protein	136	102	72	193
Crude ash	125	65	35	60
Crude fibre	263	376	183	105
NDF[a]	463	659	422	336
ADF[b]	379	426	228	145
Starch	ND	ND	373	354
NEL (MJ)	5,8	4,5	6,7	7,6
uCP[c,d]	128	109	132	183
Ruminal N balance[d,e] (g)	1	−1	−10	2

[a] Neutral detergent fibre;
[b] acid detergent fibre;
[c] ND, not determined;
[d] utilizable crude protein in the duodenum;
[e] calculated value.

ANIMALS, MATERIALS AND METHODS

Experimental design and animals

The experiment was conducted as a repeated-measure design at the organic farm of the Agricultural School Ursprung in the province of Salzburg, Austria, (570 m above sea level, 1250 mm annual precipitation, 8.5 °C average annual temperature) from December 2004 to February 2005 with 16 Holstein Friesian dairy cows, housed in a cubicle housing system with Calan gates for individual feeding. Cows were allotted randomly to two treatment groups: a control treatment group (C) and an experimental treatment group (E). The experiment lasted for 12 weeks. First, a 3-week adaptation period to the Calan gates and feeding regime was conducted, followed by a 9-week experimental period. At the beginning of the adaptation period, cows were on average (± standard deviation) 162 ± 82 days in milk. Average milk yield was 21.6 ± 4.3 kg and number of lactations 3.2 ± 2.5.

Feeding regime

In the experiment, two grass–clover silage-based rations were compared. The ingredients of the diets were grass–clover silage *ad libitum*, 1–2 kg homegrown hay, purchased, pelleted concentrates and maize silage for treatment E. Additionally, 100 g of a commercial mineral and vitamin mixture were given to each cow daily. Grass–clover silage was harvested from primary cut in mid May from 12 ha permanent grassland and 8 ha perennium clover–grass leys. Maize silage was grown on 2 ha, harvested in mid October and chopped to a length of approximately 10 mm. Taking 15% harvesting and ensiling losses into account, average dry matter (DM) yield per hectare was approximately 8.2 tonnes. The energy, starch and fibre contents of the maize silage, as described by DLG,[17] were above average contents. Chemical composition and calculated nutritive values of dietary feeds are shown in Table 1.

Feeds were offered in the following order: grass–clover silage (morning), hay (noon), grass–clover silage (evening). According to a ration optimization programme,[18,19] the latter diet would allow for the production of 14 kg milk. It was assumed that 1 kg concentrate DM contained 7.8 MJ net energy for lactation (NEL), and that for the production of 1 kg milk 3.2 MJ NEL was necessary.[20] Therefore, in treatment C, cows exceeding a daily milk production of 14 kg were fed concentrates at a rate of 1 kg DM per 2 kg additional milk yield. Concentrate intake in treatment C was adjusted to milk yield twice during the experiment. Concentrates were fed individually to each cow with a maximum of 2 kg per meal via an automatic feeding station. In treatment E, two-thirds of average herd concentrate intake (4.0 kg DM at the beginning of the experiment) was replaced with 3.0 kg maize silage DM. Due to small maize silage refusals, average maize silage DMI was 2.7 kg DM in treatment E. The amount of maize silage and concentrates fed in treatment E was kept constant throughout the experiment. Maize silage was offered in two equal portions and 15 min were allowed for consumption before feeding grass–clover silage.

Data collection, analytical procedures and data calculation

Individual forage intake was recorded during three 5-day recording periods in weeks 4, 8 and 12 of the experiment using Calan gates. Feeds, provided in an amount to ensure about 10% refusals of grass–clover silage, were removed and weighed before the next feeding. The single meals were added per day and cow and used as basic data for feed intake. Between recording periods, the amount of maize silage offered cows in treatment E was not weighed exactly, but it was estimated that one

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DOI: 10.1002/jsfa

scoopful equalled approximately 1.5 kg maize silage DM. Concentrate intake was recorded daily during the experiment. In each recording period one sample of each dietary component, pooled over 3 days, was collected and analysed according to VDLUFA[21] and ALFA.[22] Furthermore, one pooled sample of each feed refusal (grass clover silage and hay) was collected per cow and recording period and analyzed. Cows were milked twice daily at 6:00 and 16:30 h in a herringbone milking parlour and milk yields were recorded automatically at each milking. Every 2 weeks, one bulked sample of morning and evening milk was collected from each cow and analyzed for fat, protein, lactose, urea and somatic cell counts. Cows were weighed once during each recording period.

Table 2 gives the methodology, based on requirements of ruminants of the GfE (Gesellschaft für Ernährungsphysiologie),[20] for calculating the derived data.

Statistical analysis

Data were analysed using the MIXED procedure of the statistical program package SAS[23] according to the following model. Only parameters which were statistically significant were included in the final reduced model. Statistical differences were considered to be significant when $P < 0.05$ and tendential when $P < 0.10$.

$$Y_{ijklm} = \mu + T_i + P_j + (T \times P)_{ij} + D_k + W_1 + \varepsilon_{ijklm}$$

where μ = overall mean, T_i = fixed effect of treatment (E, C), P_j = fixed effect of recording period (I, II, III), $(T \times P)_{ij}$ = interaction between treatment and recording period, D_k = continuous covariate day in milk, W_1 = continuous covariate body weight before experiment, ε_{ijklm} = residual error. Cow within-treatment was defined as random effect.

W_1 was significant for intake of forage, grass–clover silage, crude fibre (CF), neutral detergent fibre (NDF) and acid detergent fibre (ADF). For analysing milk composition, the recording period was replaced by the number of control. For analysing milk yield and concentrate intake throughout the experiment the experimental day was included as fixed effect in the model.

RESULTS

Feed intake and milk production

Least-squares means, residual standard deviations (s_e) and probabilities (P) concerning feed and nutrient intake are summarized in Table 3. In treatment E, daily total dry matter intake (DMI) was significantly reduced by 9% compared to treatment C. Hence, maize silage replaced markedly greater amounts of grass–clover silage than was the case for concentrates. Forage intake per kilogram metabolic body weight tended to be increased in treatment E. Average concentrate intake in relation to total DMI was 8% in treatment E and 20% in treatment C. Average maize silage intake in treatment E was 17% of total DMI. In treatment E, the significantly lower grass–clover silage intake and the lower crude protein (CP) intake through supplements (concentrates and maize silage) were associated with 12% lower NEL and 21% lower CP intakes. Starch intake from maize silage and concentrates was numerically, but not significantly, higher in treatment E ($P = 0.517$). Starch intake as percentage of total DMI was 9.1% in treatment E as compared to 6.9% in treatment C; however, the difference was not statistically significant ($P = 0.168$). Mean NEL content per kilogram DM was 6.1 ± 0.31 MJ in both diets. Dietary CP content was $129 \pm 5.7\ \mathrm{g\,kg^{-1}}$ for treatment E and $145 \pm 9.0\ \mathrm{g\,kg^{-1}}$ for treatment C.

Significantly lower CP and NEL intakes in treatment E resulted in on average 14% lower utilizable crude protein (uCP) intakes and significantly lower ruminal nitrogen balances (RNB). RNB is a calculated value for the protein supply of ruminal microbes and uCP is a calculated value for the content of

Table 2. Methodology of calculated data according to GfE[20]

uCP (g)	$\{11.93 - [6.82 \times (\mathrm{UDP/CP})]\} \times \mathrm{ME} + 1.03 \times \mathrm{UDP}$ UDP, ruminally undegradable feed protein; ME, metabolizable energy
Ruminal N balance (g)	(CP - uCP)/6.25
Milk $\mathrm{kg^{-1}}$ DMI (kg)	Daily milk yield/daily DMI
Contentrates (g DM) $\mathrm{kg^{-1}}$ milk	Daily concentrate DMI/daily milk yield
Milk N as % of N intake	[(Daily milk yield × milk protein content)/6.25]/(daily CP intake/6.25) × 100
Milk from forage (kg)	(NEL intake from forage - NEL requirements for maintenance)/NEL requirements $\mathrm{kg^{-1}}$ milk
uCP balance (%)	(uCP intake/uCP requirements for maintenance and milk production) × 100
NEL balance (%)	(NEL intake/NEL requirements for maintenance and milk production) × 100
Requirements for maintenance (MJ NEL $\mathrm{day^{-1}}$)	$0.293 \times \text{body weight}^{0.75}$
Requirements for milk production (MJ NEL $\mathrm{day^{-1}}$)	Daily milk yield × (0.38 × milk fat percent + 0.21 × milk protein percent + 0.95)
Requirements for maintenance (g uCP $\mathrm{d^{-1}}$)	[5.9206 × log(body weight) − 6.76 + 2.19 × kg DMI + 0.018 × body weight^{075}] × 2.1 (endogenous urinary and fecal N losses + N losses via skin)
Requirements for milk production (g uCP $\mathrm{day^{-1}}$)	(daily milk yield × milk protein content) × 2.1

Table 3. Effects of substituting maize silage for concentrates on daily feed and nutrient intake

	Treatment			
Item	C	E	s_e	P
Concentrate DMI[a] (kg)	3.6	1.3	0.21	0.017
Maize silage DMI[a] (kg)		2.7		
Hay DMI[a] (kg)	1.3	1.2	0.41	0.160
Grass–clover silage DMI[a] (kg)	12.7	10.8	1.45	0.001
Total DMI[a] (kg)	17.7	15.9	1.59	0.037
Forage (silage and hay) DMI[a] (kg)	14.0	14.7	1.53	0.122
Forage DMI[a] per kg body weight$^{0.75}$ (g)	112	118	12.3	0.067
NEL intake (MJ)	109	96	8.9	0.020
Starch intake (g)	1253	1452	98.1	0.517
CP intake (g)	2576	2044	204.1	0.001
Crude fibre intake (g)	4346	4078	384.6	0.025
NDF intake (g)	7935	7367	735.0	0.030
ADF intake (g)	6007	5546	549.0	0.006
Body weight (kg)	632	618	8.7	0.668
uCP intake[b,c] (g)	2439	2101	195.4	0.007
Ruminal N balance[b] (g)	22.0	−9.1	2.84	<0.001[d]

[a] Dry matter intake;
[b] utilizable crude protein in the duodenum;
[c] calculated value;
[d] interaction treatment–recording period.

microbial protein and ruminally undegradable feed protein available in the duodenum (Table 2). For RNB, a significant interaction between treatment and recording period was observed. In the first and second recording periods RNB in treatment E was around zero (−3 and 0 g, respectively) but −24 g in the last recording period. RNB in treatment C was 28, 29 and 9 g, respectively.

Average body weight was 618 and 632 kg in treatments E and C, respectively. Neither a significant effect of treatment on body weight ($P = 0.668$) nor an interaction between treatment and recording period was observed.

Table 4 shows data for milk yield and milk composition. In treatment E, actual milk yield throughout the whole experiment dropped by 2.2 kg per day, which was not statistically significant. Milk composition was not affected by treatment, except for milk urea content, which was significantly lower in treatment E (14.1 *versus* 16.6 mg 100 mL^{-1}). Figure 1 shows changes in milk yield and concentrate intake throughout the experiment.

Calculation of feed utilization efficiency

Table 2 gives the methodology for calculating the derived data shown in Table 5. Estimated milk yield from forage was significantly higher in treatment E (91% versus 71%). Calculated efficiency of dietary nitrogen utilization (N in milk as percentage of N intake) showed a significant interaction between

Table 4. Effects of substituting maize silage for concentrates on milk production traits

	Treatment		s_e	P
Item	C	E		
Milk (kg day^{-1})	19.7	17.5	1.18	0.186
Protein (g kg^{-1})	31.5	31.2	0.91	0.744
Fat (g kg^{-1})	40.2	40.5	3.89	0.809
Lactose (g kg^{-1})	47.9	47.9	0.97	0.939
Fat protein ratio	1.25	1.29	0.129	0.296
Protein yield (g)	630	545	50.3	0.139
Fat yield (g)	787	703	116.2	0.317
Somatic cell counts ($\times 10^3$ mL^{-1})	85	125	64.5	0.376
Urea (mg 100 mL^{-1})	16.6	14.1	2.48	0.019

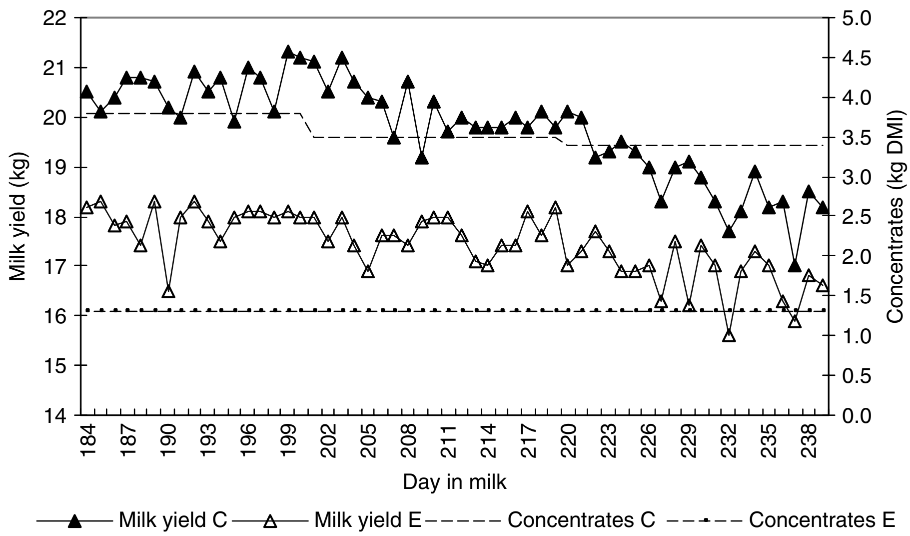

Figure 1. Milk yield and concentrate intake throughout the experiment in treatments E and C.

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DOI: 10.1002/jsfa

treatment and recording period. Therefore, the main effect is presented in Table 5 and the results of the single recording periods in Fig. 2. Balances of uCP and NEL (intake as percentage of requirements for maintenance and observed milk production) were not statistically significant and were positive in both treatments.

DISCUSSION

For the study in question, two-thirds of average herd concentrate intake was replaced by maize silage on a dry matter basis. Hence, treatment E and C differed in three factors: concentrate level, dietary CP content and use of maize silage as a supplement. Therefore, all three factors have to be considered in light of the present results.

Feed intake and milk production

In the present study, daily total DMI as well as DMI per kilogram metabolic body weight (129 *versus* 141 g, $P = 0.050$) were considerably lower in treatment E, which is typical when concentrates are excluded from forage-based diets.[24–27] Furthermore, Gruber *et al.*[19] analysed feeding trials from 10 research institutes to predict feed intake equations and state that increase in feed intake is markedly higher when supplementing with concentrates than with maize silage, a finding which is also described by Phillips.[28] The reason for this, besides a probably higher palatability of the concentrate mixture, might be nutritive differences between concentrates and maize silage. Maize silage has a higher fibre and moisture content, a higher undegradable fraction and a slower degradation rate of the potentially degradable fractions,[10,29] which, although not measured in the present study, may result in a longer ruminal retention time and lower consumption rate.

Table 5. Calculated feed utilization efficiency due to substituting concentrates with maize silage

Item	Treatment C	Treatment E	s_e	P
Milk (kg) kg^{-1} DMI	1.09	1.11	0.129	0.815
Concentrates (g DM) kg^{-1} milk	165	67	13.9	0.011
Milk from forage[a] (kg d^{-1})	14.0	15.9	2.81	0.027
Milk N as % of N intake	23.7	27.0	3.01	0.031[a]
uCP balance (%)	117.6	113.8	6.51	0.156[a]
NEL balance (%)	109.7	104.4	9.41	0.084[a]

[a] Interaction treatment–recording period.

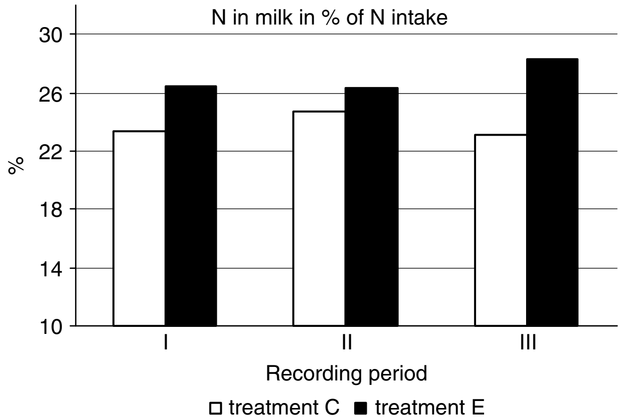

Figure 2. Least-squares means for dietary N utilization efficiency in the three recording periods in treatments E and C.

The substitution rate is defined as the change in forage DMI per additional kilogram of concentrate and depends on roughage quality, concentrate level, type of concentrate and energy balance of the cow.[24] Forage intake was numerically higher in treatment E (14.7 *versus* 14.0 kg); however, at 0.30 kg DM, calculated forage increase per kilogram concentrate reduction was markedly below expectations.[19,26] An explanation for the low increase in forage intake in treatment E might be the moderate grass–clover silage quality (5.8 MJ NEL; 136 g CP; pH 4.2; 9.4% ammonia N of total N; 39, 12 and 5 g kg^{-1} DM of lactic, acetic and butyric acid, respectively) and the moderate concentrate level in treatment C (20% of DMI). The calculated substitution rate of grass–clover silage per kilogram of maize silage was 0.70 kg on a DM basis. Mitani *et al.*[30] supplemented diets for grazing dairy cows with 2 and 4 kg maize silage DM above energy requirement and found a reduction in herbage intake of 0.80 and 0.45 kg DM, respectively, as compared to the non-supplemented group. Phillips[28] cited substitution rates of pasture with maize silage within a range of 0.47–1.40 kg DM. Taking into account that in the present trial concentrate intake in treatment E was markedly reduced as well, the substitution rate of 0.70 kg DM was higher than expected.

According to Mertens,[31] feed intake depends on NDF intake as well as on other feed characteristics. High dietary NDF content implies that feed intake is regulated by physical limitation and not physiological regulation. In treatment E, NDF content per kilogram DM intake was slight but significantly higher (462 *versus* 447 g, $P = 0.001$). However, total NDF intake was 8 percentage points lower in treatment E as compared to treatment C ($P = 0.030$). Furthermore, feed intake on a fresh matter basis was numerically lower in treatment E (46.8 and 48.6 kg, respectively, $P = 0.164$). Hence, it is unlikely that feed intake in treatment E was primarily restricted by digestive tract capacity.

In cattle feeding, both the animal and its ruminal microbes have to be supplied with sufficient energy and protein. In the present feeding trial, in treatment E NEL intake was reduced by 12% and CP intake by 21% compared with treatment C.

The present trial does not rely on invasive examination; hence valuable indicators for estimating the protein supply of the ruminal microbes were milk urea concentration[32–35] and RNB.[20] According to Austrian recommendations, milk urea concentration should ideally be between 15 and 30 mg 100 mL^{-1}.[36] The GfE[20] states that up to 20% of the nitrogen demand of the ruminal microbes can be recycled by the rumino-hepatic cycle, meaning that a slight ruminal N undersupply is tolerable. Tolerable ruminal N undersupply is calculated as 50 minus daily milk yield in kilograms.[37] In terms of milk urea content, ruminal protein supply in treatment E was below the recommended range, while RNB was still within the recommended range. However, RNB is only an estimated parameter from feed analyses and therefore RNB was probably slightly overestimated, which would be in accordance with Steinwidder and Gruber,[38] who found a well-balanced RNB when milk urea concentration was 21 g. According to Paulicks and Kirchgessner,[39] milk protein content is strongly influenced by energy supply, but protein supply has only a small impact. In the present trial, milk protein concentration was similar in both treatments, with an average of 31.4 g.

Energy balance was closer to zero than protein balance and protein balance was not significantly different between treatments. Nevertheless it is speculated that protein supply was first limiting in treatment E: firstly, because of the markedly lower CP than NEL intake; secondly, because of the significantly reduced milk urea content and RNB; and thirdly, due to the lack of differences in milk protein content. A suboptimal ruminal protein supply leads to reduced microbial activity, decreased ruminal degradation rate and feed digestibility and consequently to reduced feed intake and milk yield.[39] Hence, reduced feed intake in treatment E might be attributable to a lower protein supply, lower concentrate use and, as mentioned above, longer ruminal retention time and lower consumption rates of maize silage as compared with concentrates.

Milk yield dropped from 19.7 to 17.5 kg in treatment E, which might be due to lower energy and protein intake in treatment E. Decreases in milk yield due to dietary protein reduction are in general agreement with several studies.[34,35,39,40] However, the findings are contradictory to those of Kröber *et al.*,[33] who fed diets with three different dietary CP contents (13.7%, 12.5% and 10.6% on a DM basis) over the entire lactation period. In this study, although total DMI decreased, no decrease in milk yield was observed. In the study in question, differences in milk yield were not significant ($P = 0.186$), but numerically high. Therefore, it is suggested that when repeating the experiment with a larger and more homogenous dairy herd differences would become significant.

Calculation of feed utilization efficiency

Feed utilization efficiency can be expressed differently and depends on dietary and animal characteristics as well as feeding management. In the present study, conversion efficiency of concentrates into milk, defined as difference in average milk yield between treatment E and C divided by difference in average concentrate intake, was rather poor in treatment C, with 1.0 kg concentrates DM per additional kilogram of milk. Figure 1 shows that at the end of the experiment milk yield in treatment C approaches that of treatment E, showing that, especially in a late stage of lactation, the benefit of concentrate supplementation is low. Calculated concentrate intake per kilogram of milk production was 60% lower in treatment E than in treatment C (67 and 165 g, respectively). Furthermore, calculated milk production from forage was, at 91%, markedly higher in treatment E than in treatment C and similar to a self-sufficient organic dairy system based on high forage diets and solely home-grown concentrates examined by Weller and Bowling.[41]

Conversion of dietary N into milk N is an easily calculated and commonly used parameter to express nitrogen efficiency. Tamminga[13] notes that maximum N efficiency in milk production is below 30%. Goelema *et al.*[42] concluded that values of 25% or higher could be reached solely at dietary crude protein levels of 12–15%. Contrary to these results, Huhtanen *et al.*[43] analyzed data from 55 mainly Finnish production experiments and reported an average N efficiency of 28%, ranging from 20% to 39%. In the present feeding trial, N efficiency was, with an average of 27%, three percentage points higher in treatment E than in treatment C. The significant higher efficiency in the third recording period for treatment E was due to smaller differences in milk yield between the treatments, which are shown in Fig. 1. Several authors describe an increase in N efficiency due to reduced concentrate level, dietary CP content or supplementation of maize silage.[15,34,40,44,45] In the present study, these three factors are confounded; therefore it is not possible to make a reliable statement about which factor had the most influence.

In the present study, cows of both treatments were above recommendation with regard to their protein and energy requirements.[20] That might be explainable, as the average stage of lactation throughout the experiment was 211 days in milk, and with a progressing stage of lactation the response to additional protein and energy declines,[3] nutrients and energy are also partitioned to body tissues, which was not considered in the present calculations.[20] However, body weight did not seem to increase throughout the 9-week experimental period. Therefore, speculations on the influence of body weight changes on milk yield or energy and protein balances seem to be too speculative. The observation that in the second recording period body weight was numerically lower in both treatments than in the other recording periods (637, 628 and 631 kg, respectively, in the three recording periods in treatment C and 621, 610 and 624 kg, respectively, in treatment E) might be due to the fact that cows were not kept separated from water troughs prior to weighing, different rumen fills or possibly due to the

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DOI: 10.1002/jsfa

heterogenous herd. Reasons for both positive protein and energy balances could be the following: provision of grass–clover silage *ad libitum* for the whole day, a slight overestimation of the uCP feed value as well as discrepancies in the estimation of the protein and energy requirements of the GfE.[20]

Energy balance in treatment C was similar to that of a Dutch study conducted by Kristensen and Mogensen[46], who examined 14 organic dairy herds with average concentrate levels of 1200 kg per lactation. Although protein and energy balance did not differ significantly between treatments, a numerically improved feed balance was observed in treatment E. This is partly in accordance with Sehested *et al.*,[26] who decreased concentrate levels from 39% to 19% of DMI and observed a marked increase in energy efficiency. However, decreasing the concentrate level from 19% to 0% of DMI resulted in only a marginal improvement in energy efficiency. Steinshamm and Thuen[45] fed two different concentrate levels (5% and 25% concentrates of total energy intake) to cows in a similar lactation stage to those in the present trial and found no difference in energy balance, but protein balance improved significantly in the low-concentrate diet. Nevertheless, protein intake was 23% above requirements even in the low-concentrate diet, which is a markedly higher oversupply than in the present study. Contrary to these results, Mitani *et al.*[30] supplemented grazing dairy cow diets with 2 and 4 kg maize silage DM above energy requirement and did not find any difference in nitrogen and energy use. Therefore they concluded that feed efficiency was probably limited by low dietary nitrogen content.

The hypothesis that the substitution of purchased concentrate mixture with farm-grown maize silage would decrease daily milk yield by less than 5% has to be rejected. In the present study, milk yield decrease was 11%. The hypothesis that dietary nitrogen efficiency would be improved was proven; however, no reliable statement can be made regarding whether this improvement was due to concentrate reduction, reduction in dietary CP content or supplementation of maize silage.

CONCLUSIONS

Protein supply was relatively low in treatment E supplemented with maize silage, as indicated by milk urea concentration and ruminal nitrogen balance. Hence, when supplementing grass–clover silage-based diets with maize silage, silage quality should be taken into account so that ruminal protein supply does not become limiting. Despite a decrease in milk yield of 11%, milk production from forage was considerably improved and concentrate input per kilogram of milk markedly reduced. Furthermore, a tendency towards an improved nitrogen efficiency and feed balance was observed. The present feeding trial indicates a potential to reduce concentrate levels and substitute them with maize silage in organic dairy cow rations at least in the second half of lactation.

ACKNOWLEDGEMENTS

The authors would like to thank the Agricultural School Ursprung, 5161 Elixhausen, Austria, for providing its stable and dairy herd and the farm staff for contribution to the experimental work. The authors would also like to express their thanks to the Austrian Ministry of Agriculture and Forestry, Environment and Water Management, to the Salzburger Landesregierung, Raiffeisenverband, Salzburg, and Bio Austria for funding the project.

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DOI: 10.1002/jsfa