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Feed, N and P utilisation of Brown Swiss heifers in comparison with Angus and Simmental suckler cows with their progeny grazing mountain pastures

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Abstract

The aim of the present study was to compare intake and nutrient turnover in two major production systems on mountainous pastures, suckler beef production and rearing of heifers. Data from 4×6 Angus or Simmental suckler beef cows with Angus sired calves were opposed to those measured in six growing Brown Swiss heifers applying a contrast model. In each of two vegetative seasons (years A and B) animals were kept together on three mountainous pastures, P1 (1 000 m a.s.l.), P2 and P3 (both 2 000 m a.s.l.), providing either first growth (P1, P2) or re-growth herbage (P3). Intake and herbage digestibility were estimated by the double alkane indicator technique. On average of the two years, the cows together with their progeny weighed 741 kg and the heifers 374 kg. The average daily body weight gain in beef calves (1 044 g) was twice of that measured in the heifers (546 g). Body weight of the cows remained quite constant on average. Dry matter intakes were 17.0 and 8.2 kg/d, and 118 and 96 g/kg$^{0.75}$ body weight in suckler cows with progeny and heifers, respectively. On all pastures, cattle of both categories selected herbage of similar energy and protein content. Digestibilities of organic matter (73-74%) and fibre (NDF, 69%) were similar between categories, though differing among pastures. Nitrogen utilisation was equal in both categories (8% of intake), but varied among pastures (11%, 8% and 5% on P1, P2 and P3, respectively) and years (11% and 6% in years A and B) due to different herbage N contents and intakes. When related to intake, also excretion of faecal and urinary N was equal in both categories. Faecal P losses relative to weight gain were similar in both categories but differed between pastures and years. The results demonstrated unexpectedly similar nutrient use efficiencies and relative N and P losses of the two livestock system options currently common in utilising of mountainous pasture.

Keywords: suckler beef, heifers, cattle, herbage, nitrogen, phosphorus, pasture

Zusammenfassung

Futter-, N- und P-Verwertung von Brown Swiss-Färsen im Vergleich zu Angus- bzw. Simmentalmutterkühen mit Kälbern auf Gebirgsweiden

Das Ziel der vorliegenden Studie war es, Futteraufnahme und Nährstoffumsatz in zwei bedeutsamen Produktionssystemen auf Alpweiden zu vergleichen, nämlich Mutterkuhhaltung und Färsenaufzucht. Daten von 4×6 Angus- oder Simmentalmutterkühen mit Kälbern von Angusvätern wurden mittels eines Kontrastmodells mit denjenigen verglichen, die bei sechs Brown Swiss-Färsen erhoben wurden. In insgesamt zwei Vegetationsperioden (Jahre A und B) wurden die Tiere zusammen auf drei Gebirgsflächen geweidet: P1 (1 000 m ü. NN), P2 und P3 (beide auf 2 000 m ü. NN), wobei es sich entweder um den ersten Aufwuchs (P1, P2) oder um den zweiten Aufwuchs (P3) handelte. Futteraufnahme und -verdaulichkeit wurden mit der doppelten Alkanindikatortechnik bestimmt. Im Durchschnitt der beiden Jahre wogen die Kühe zusammen mit ihrem Nachwuchs 741 kg und die Färsen 374 kg. Die mittleren Tageszunahmen der Kälber (1 044 g) waren doppelt so hoch wie diejenigen der Färsen (546 g). Die Lebendmasse der Kühe blieb im Durchschnitt relativ konstant. Die Trockenmasseaufnahmen der Mutterkühe und -kälber sowie der Färsen betrugen 17,0 bzw. 8,2 kg/Tag und 118 bzw. 96 g/kg$^{0.75}$ Lebendmasse. Auf allen Weiden selektierten Rinder beider Kategorien Futter mit ähnlichem Energie- und Proteingehalt. Die Verdaulichkeiten der organischen Masse (73-74%) und der Faser (NDF, 69%) waren zwischen Kategorien ähnlich, variierten aber zwischen den Weiden. Die N-Verwertung war im Mittel in beiden Kategorien gleich (8% der Aufnahme), unterschied sich aber zwischen Weiden (11%, 8% bzw. 5% auf P1, P2 bzw. P3) und Jahren (11% und 6% in den Jahren A und B) aufgrund unterschiedlicher N-Gehalte des Futters und Futteraufnahmen. Bezogen auf die N-Aufnahme waren die N-Verluste mit Kot und Harn zwischen den Kategorien ebenfalls gleich. Die P-Verluste in Relation zu den Zunahmen waren in beiden Kategorien gleich, variierten aber zwischen Weiden und Jahren. Die Ergebnisse belegen, dass Nährstoff-, N- und P-Verwertung in den beiden gebräuchlichen Optionen an Nutztiersystemen zur Nutzung von Gebirgsweiden anscheinend unerwartet ähnlich sind.

Schlüsselwörter: Mutterkuh, Färse, Rind, Raufutter, Stickstoff, Phosphor, Weide

Introduction

Mountainous pastures were traditionally used for summer grazing of dairy cows or growing heifers as the two components of the milk production system. As dairy cow number is declining since some time and mountainous pastures do not provide herbage of sufficiently high nutrient density for either higher yielding or early-lactating dairy cows (BERRY *et al.* 2001, LEIBER *et al.* 2006), other livestock system options gained comparative advantage. This trend is supported by current policy measures facilitating agricultural management of less favoured areas (D'HOUR *et al.* 1998). Furthermore, there is a renewed interest in grazing due to the expected improvements in the dietetic value of the products (COULON and PRIOLO 2002, RAZMINOWICZ *et al.* 2006). However, animals grazing biodiverse mountainous pastures are also challenged by the complexity of this situation and the rough climate and the unfavourable topographic conditions (MALOSSINI *et al.* 1995, SCHUBIGER *et al.* 1998). Alpine summer grazing is known to impair performance and metabolic status of dairy cows (BERRY *et al.* 2001) but in turn might improve constitution, physical health and life-time performance of dairy cows when having experienced high-alpine grazing before the first parturition (RUHLAND 1983). Unless a slowly growing beef breed is used (BERRY *et al.* 2002), mountainous pastures may also be limiting in terms of milk yield of suckler cows and maximal weight gain of their progeny

(DRENNAN 1984), this directly in later stage of lactation when calves have to consume more forage (ESTERMANN *et al.* 2002). Finally, extensive grasslands do not guarantee low N losses to the environment (SCHELLBERG *et al.* 2007), and differences in body N and P retention might play an important role in N and P utilisation from forage of these grasslands as well as emissions of these nutrients from livestock husbandry.

The hypothesis tested was that switching from keeping heifers of a dairy breed to suckler cows from beef breeds would increase dietary nutrient, N and P utilisation on mountainous pastures as a response to the comparatively high body weight (BW) gain in the beef calves. From results on plant selection found with dry and lactating beef cows on extensive pastures (FARRUGGIA *et al.* 2006) it was also expected that different animal categories might express a different plant species selection pattern depending on their individual demand. Comparisons among livestock system options in N and P losses obtained simultaneously and under controlled conditions are essential to get an environmentally-based decision tool. For alpine pastures these comparisons have been performed so far only between dairy cows and suckler beef (ESTERMANN *et al.* 2001, BERRY *et al.* 2002). The present investigation complements these comparisons by opposing suckler beef and growing heifers kept on mountainous pastures located at different altitudes.

Material and methods

Experimental design

A total of six growing heifers and 24 suckler cows with their progeny (further on called ›suckler units‹) grazed together. Thereof three heifers and 12 suckler units were used in each of two grazing seasons (years A and B). Heifers were of the Brown Swiss breed and had an average age of 519 (±18) and 691 (±15) d at the start of the respective first measurement periods of years A and B. Half of the suckler cows were of original Swiss Simmental breed (>99% Simmental blood proportion), the other half were of Angus breed. Suckler cows were bred with 12 different Angus sires. The average lactation number of the cows used in the 2 years was 1.1 (±0.3) and 2.3 (±0.6), respectively. Calving periods were late autumn or late winter in half of the cows of each breed. At the start of the measurements the average ages of the calves were similar in years A and B with 115 d and 131 d, respectively. These four sub-groups (breed × calving period) of six suckler units each were balanced in calf gender. Suckler beef breed group differences were the focus of another research question, the results of which have been described in ESTERMANN *et al.* (2003). Different from that study, in the present investigation also a differentiation by season was made and suckler unit data were combined and opposed to heifer data by a contrast approach.

The investigations were carried out on three experimental pastures in main measurement periods of 7 d each with continuous data and sample collection. During adaptation periods of 10 d, animals grazed on sites adjoining to the experimental paddocks. Grazing on P1 started on 11 and 18 May in years A and B, respectively. The measurement periods on pasture P2 followed P1 after 5.5 weeks (with the animals being transferred to high altitude 3 weeks after finishing grazing on P1), and P3 was investigated 3 weeks after finishing grazing on P2. Other pastures were provided in the time between. The size of all paddocks was determined from the estimated sward mass in order to provide always sufficient amounts of feed. Animals of all experimental groups were grazing together in the same paddocks. The respective first experimental pasture (P1) was located at 1 000 m a.s.l. (subalpine) and had a slight inclination and was north-west facing. At the time of grazing, herbage was of first growth in late vegetative stage in both years. On the experimental swards 21 plant species were found, with grasses, legumes and herbs covering 86, 2 and 12% of the paddock surface, respectively. Pastures P2 and P3 were located at 2 000 m a.s.l. (alpine; i.e., above the tree line) with medium inclination and were south-west facing. Pasture P2 was first growth in medium to late vegetative stage, P3 was re-growth in its early vegetative stage on a site which had been grazed earlier in the same season. The P2 and P3 swards contained about 70 different plant species, and grasses, legumes and herbs covered about 37, 23 and 40% of the surface, respectively. The ambient temperatures recorded during the 7-d main experimental periods on the three pastures only slightly differed between years A and B, but varied from 4.1 to 20.3 C within year. Only small period differences were found in air humidity which varied from 69.2 to 83.6%. Precipitation was generally low in year A. A high average daily precipitation of 13.3 and 9.6 mm was measured during P1 and P3 measurements in year B, whereas in the corresponding P2 period no rainfall occurred.

The animals had permanent access to fresh water and to a 1:1 mixture of NaCl and a mineral premix provided as a powder in a bowl (for composition see ESTERMANN *et al.* 2003). The experiment was approved by the Cantonal Veterinary Office of Zug as the responsible authority.

Sampling and analysis

In the measurement periods, individual BW was recorded from each experimental animal every morning at about 06:00 h and, additionally, every second week throughout the whole experiment. Data on BW used for further calculations refer to the average of the 7-d measurement periods, while daily BW change was calculated from the differences found across the entire 21-d periods.

The composition of the standing sward was determined on each pasture and in each year by collecting about 50 samples per paddock from 20×20 cm^2 quadrates every 10 m along a diagonal transect. Within the quadrates all vegetation was cut to 3 cm height and all samples of one paddock were combined to one sample and frozen at −20 °C. For the determination of nutrient intake and digestibility by the double indicator technique as described by MAYES *et al.* (1986), controlled release alkane capsules (CRC, Captec Ltd. Auckland, New Zealand) were orally introduced into the rumen of all heifers, cows and calves 7 d prior to the respective main experimental periods as outlined previously (BERRY *et al.* 2000). The CRCs released C_{32} (and C36) alkanes at a stated steady batch release rate. The intervals between the measurement periods were always long enough to ensure that previously dosed CRCs were completely empty (BERRY *et al.* 2000). Cows and heifers received type MCM capsules (suitable for cattle of 300 to 650 kg BW) and calves, depending on BW, either type SP (50 to 100 kg BW) or type YC (100 to 300 kg BW). Spot faeces samples were collected from fresh dung pads or rectally at dawn over the 7 d of measurement, which fell into the recommended sampling window for the CRCs.

Feed selection behaviour of the animals was imitated by hand-plucking of herbage samples for a total of 12 h/d by two persons switching between groups and following the detailed principles of BERRY *et al.* (2002) for the collection procedure. In order to account for the delay in excretion, herbage sampling started and ended 1 d before faeces collection. In line with BERRY *et al.* (2001), for calculation of intake and digestibility the $C_{31}:C_{32}$ ratio was used when applying the equations of MAYES *et al.* (1986). The OM digestibility could not be calculated in the calves due to the unknown milk consumption. Phosphorus (P) supply through the mineral supplement was estimated from the total consumption of the complete groups assuming that intake per kg BW was constant. This simplification seems justified since this P amount did not exceed some 10% of total P intake.

Faeces and herbage samples were frozen at −20 °C, subsequently defrosted and pooled either by individual animals or by experimental groups for later analysis. Subsamples of faeces were refrozen for later nitrogen (N) analysis. Other faecal subsamples and herbage were dried at 60 °C in a ventilated oven for 48 h. Analysis of samples was done as previously described in detail in ESTERMANN *et al.* (2001, 2003). Briefly, dried and milled (0.75 mm sieve) feed and faeces samples were analysed for their contents of dry matter (DM), organic matter (OM), nitrogen (N), phosphorus (P) and neutral detergent fibre (NDF) using standard protocols (VAN SOEST *et al.* 1991, AOAC 1995, NAUMANN and BASSLER 1997). Contents of n-alkanes (C_{31} and C_{32}) were analysed by gas chromatography (BERRY *et al.* 2000). Herbage contents of metabolisable energy (ME) and absorbable protein at the small intestine (PDI) were calculated from nutrient analyses applying the RAP (1999) equations. Body N retention was estimated assuming a content of 26 g N per kg of BW change (GIBB *et al.* 1992) in all animals (cf. ESTERMANN *et al.* 2003). It is acknowledged that this assumption carries uncertainties but as virtually all animals were either gaining BW (calves and heifers) or at least not losing substantial amounts of BW (cows), this simplification seems justified. Since urine was not quantitatively collected, urine N excretion was estimated from N intake less body N retention and faecal N loss. The latter was computed from faecal output as derived from the alkane data.

Statistical evaluation

The procedures applied in this study allowed to obtain individual data on cows, calves and heifers kept in one group. This approach was preferred to set-ups with the animals grazing individual and differing pastures (discussed in ESTERMANN *et al.* 2003). For the comparison of the livestock categories, the suckler cow plus progeny were mostly statistically treated as units (DRENNAN and MCGEE 2009). Because of the malfunction of capsules, five out of 90 datasets (two suckler cows each in P1 of years A and B, and one heifer in P1 of year A) were omitted in the statistical evaluation. All analyses were performed with SAS (2001). A mixed model procedure (method=ml) was used in analysis of variance which accounted for the repeated measures character of the data. With attention to Schwarz's Bayesian criterion the optimal covariance structure was determined (LITTELL *et al.* 1998). As there were different animal numbers in the two categories, the basic experimental groups with six animals each (one group of heifers, four groups of suckler cows with their progeny across both years) were taken into account in the model used for the statistical analyses. The fixed effects experimental groups (G), pasture (P), year (Y) and all possible interactions were analysed in one model (n=85 observations) reading

$$Y_{ijklm} = \mu + G_i + P_k + Y_l + (G \cdot P)_{ik} + (G \cdot Y)_{il} + (P \cdot Y)_{kl} + (G \cdot P \cdot Y)_{ikl} + V(d_{ij}) + \mathrm{cov}(e_{ijklm}) \qquad (1)$$

The comparisons of suckler beef and heifers and the calculation of the respective overall least square means for the two categories were obtained from contrast analysis where the four suckler beef groups were opposed to the heifer group. Pasture × year least square (LS) means of either suckler beef or heifers were calculated by analysing data separately for the two categories. For that, the model described above was simplified by omitting experimental groups and experimental group interactions. The multiple comparisons of these LS means were performed by Tukey's procedure. When comparing the categories in BW gain, and N and P data per unit of BW gain, only BW change of the calves was considered in analysis of variance because of the high extra variation brought in by the cows' BW changes. This seems also justified as the means of the overall BW change of the complete suckler units did not differ much from BW gain of the calves alone. The tables give the overall LS Means for the two livestock categories (n=24 for suckler beef and n=6 for heifers) and the LS means of the data measured in years A and B on the three pastures (n=12 for suckler beef and n=3 for heifers). Furthermore the standard error (SEM) of the overall LS means (n=6), and the P-levels for the contrast used for comparison of the categories, group, pasture, year and the interactions of experimental group with the other effects are given.

Results

The analysed composition of the standing sward found on the three pastures in the two subsequent years varied widely for some variables (Table 1). Pastures particularly differed in contents of CP (high in re-grown P3 herbage), P (low in alpine pastures) and C_{31} (high in alpine pastures). Herbage of P1 was rich in NDF compared to P2 and P3 herbages. Year B herbage was lower in DM content than that of Year A. By contrast, differences in contents of energy and PDI were low in comparison to that. The nutrient composition of the herbage simulated to have been selected by the animals was relatively similar to that found in standing herbage with >90% of the variation in nutrient content of the selected herbage being accounted for in the correlations with standing herbage. Deviation from the line of equality was mostly low in OM, NDF and ME content. At low CP and PDI content in standing sward, animals selected herbage of even lower contents while the difference was small at high concentrations. Herbage selected by cows and, particularly, by calves and heifers had a lower P content than the standing sward. Additionally, calves and heifers, but not the cows, were found to select a diet richer in NDF than that offered.

Suckler unit BW was twofold higher than in the heifers, and animals of both categories had a higher BW in year B compared to year A corresponding to the higher age of the animals of all categories (Table 2). Daily BW gains were similar between pastures, but 1.85fold higher in calves than in heifers. Suckler cows on average showed a BW change of −17, +148 and −39 g/d on P1, P2 and P3, respectively (data not shown in table). This meant overall a merely negligible BW change of +30 g/d (3% of the entire suckler unit BW gain). The average daily dry matter intake (DMI) in the suckler units was twofold of that noted in the heifers, but was quite similar when related to metabolic BW ($BW^{0.75}$) and particularly to absolute BW. In year B, DMI was significantly higher in both livestock categories than in year A. When related to BW and $BW^{0.75}$, year B DMI was still higher on P2 and P3 than in year A in the suckler units, while in all other cases year differences had disappeared. In both years and in both categories, DMI in relation to BW increased with time, particularly from P1 to P2. Feed conversion efficiency (BW gain per unit of DMI) was approximately equal in both categories. Efficiencies were lower in year B than in year A. Digestibilities of OM (cows only in the suckler units) and NDF (cows alone: 69.3 %) were equal in both categories, but differed between pastures and years (only OM). In both categories, NDF digestibility was low on P2, high on P1 and intermediate on P3.

Table 1
Nutrient composition (per kg DM) of the herbage offered in years A and B on pastures P1, P2 and P3 as well as coefficients of the regression equations (Y=a+bX) on the relationship between composition (g/kg DM) of the standing (X) and selected herbage (Y) over both years and all three pasture types

Nährstoffzusammensetzung (je kg Trockenmasse) des in den Jahren A und B auf den Weiden P1, P2 und P3 angebotenen Raufutters sowie Koeffizienten der Gleichungen der Regressionen (Y=a+bX) zum Zusammenhang zwischen der Zusammensetzung (g/kg Trockenmasse) des Aufwuchses (X) und des selektierten Raufutters (Y) über beide Jahre und alle drei Weiden

	Year	DM[1], g	OM, g	CP, g	P, g	NDF, g	ME, MJ	PDI, g	C_{31}, mg
Nutrient composition									
P1, 1 000 m a.s.l.	A	231	925	139	3.43	549	10.71	99	118
	B	169	909	142	3.60	600	9.54	93	107
P2, 2 000 m a.s.l.	A	236	932	130	2.18	497	10.71	98	393
	B	188	922	144	2.35	486	10.71	101	218
P3, 2 000 m a.s.l.	A	239	903	181	2.24	497	10.86	107	254
	B	194	891	163	1.99	457	10.64	102	182
Regression equations									
Cows, n=24									
a			31.4	−49.5	−0.03	21.5	−1.82	−34.8	76.1
b			0.96	1.28	0.94	0.92	1.17	1.13	0.49
rsd			7.65	7.88	0.12	20.4	0.18	2.34	31.1
r			0.93**	0.95**	0.98***	0.95**	0.96**	0.95**	0.83***
Calves, n=24									
a			25.1	−44.3	−0.01	−99.6	−1.95	−33.3	80.0
b			0.97	1.23	0.87	1.19	1.19	1.32	0.46
rsd			6.13	6.17	0.11	7.93	0.14	1.91	23.2
r			0.96**	0.95**	0.98***	0.98***	0.97***	0.95**	0.89***
Heifers, n=6									
a			1.16	−63.6	0.23	−55.5	−2.44	−34.6	84.2
b			0.99	1.38	0.81	1.10	1.23	1.33	0.48
rsd			7.85	10.2	0.08	7.90	0.15	2.76	22.6
r			0.93**	0.94**	0.99***	0.99***	0.98***	0.93**	0.89*

DM dry matter, OM organic matter, CP crude protein, NDF neutral detergent fibre, ME metabolisable energy, PDI absorbable protein at the duodenum (the latter two calculated according to RAP (1999), C_{31} alkane with 31 C atoms, rsd residual standard deviation, r correlation of standing to selected herbage nutrient content, *$P<0.05$, **$P<0.01$, ***$P<0.001$, [1] g/kg original substance

Table 2
Effect of experimental group (G), pasture type (P) and year (Y) on body weight and weight gain, DM intake and feed conversion efficiency, as well as nutrient digestibility[1]

Einfluss der Versuchsgruppe (G), der Weide (P) und des Jahres (Y) auf Lebendmasse, Zunahmen, T-Aufnahme, Futterverwertung und Nährstoffverdaulichkeit

Category		Suckler cow & calf				Heifer						*P*-value					
Year/Pasture	Y	P1	P2	P3	Mean	P1	P2	P3	Mean	SEM	Contrast[2]	G	P	Y	G×P	G×Y	G×P×Y
Body weight (BW)																	
Absolute, kg	A	655^{e}	694^{d}	714^{bc}	741	304^{z}	349^{y}	361^{y}	374	11.6	<0.001	<0.001	<0.001	<0.001	0.003	0.015	0.059
	B	756^{cd}	801^{b}	824^{a}		394^{x}	412^{t}	422^{t}									
Gain[3], g/d	A	1 569^{a}	1617^{a}	1033^{ab}	1 056	723	566	483	550	46.9	<0.001	<0.001	0.488	<0.001	0.179	0.004	0.074
	B	519^{b}	750^{b}	1000^{ab}		388	493	599									
Herbage DM intake																	
kg/d	A	12.4^{c}	15.4^{b}	16.4^{b}	17.0	5.6^{z}	8.3^{xy}	9.0^{tx}	8.2	0.59	<0.001	<0.001	<0.001	<0.001	<0.001	0.169	0.219
	B	14.3^{bc}	20.7^{a}	22.2^{a}		6.3^{yz}	9.1^{tx}	10.6^{t}									
% of BW/d	A	1.93^{d}	2.20^{cd}	2.28^{bc}	2.27	1.85^{yz}	2.39^{xy}	2.49^{x}	2.18	0.067	0.246	0.018	<0.001	0.007	0.472	0.055	0.573
	B	1.90^{cd}	2.58^{ab}	2.69^{a}		1.61^{z}	2.22^{xy}	2.52^{x}									
g/kg BW$^{0.75}$ and d	A	97^{c}	113^{bc}	118^{b}	118	77^{yz}	103^{xy}	109^{x}	96	3.6	<0.001	<0.001	<0.001	<0.001	0.003	0.190	0.326
	B	100^{bc}	137^{a}	144^{a}		72^{z}	100^{xy}	114^{x}									
kg/kg weight gain[3]	A	10.7^{b}	12.9^{b}	15.2^{b}	17.4	10.1	18.1	23.6	22.1	2.73	0.142	0.135	0.157	0.002	0.308	0.377	0.053
	B	17.1^{b}	25.6^{a}	23.1^{a}		39.4	22.8	18.8									
Digestibility, %																	
Organic matter[4]	A	74.4^{ab}	76.9^{a}	73.4^{b}	74.1	76.7^{y}	75.1^{y}	75.5^{y}	73.4	0.40	0.841	0.206	<0.001	<0.001	<0.001	<0.001	<0.001
	B	69.8^{c}	74.4^{ab}	74.6^{ab}		68.2^{z}	72.9^{yz}	72.7^{yz}									
Neutral detergent fibre	A	70.7^{a}	67.4^{ab}	66.3^{b}	69.0	76.1^{y}	64.6^{z}	70.0^{yz}	69.0	0.62	0.985	0.417	<0.001	0.341	<0.001	0.072	0.003
	B	69.9^{ab}	68.7^{ab}	69.9^{ab}		69.3^{yz}	66.4^{z}	69.8^{yz}									

[1] LS Means carrying no common superscript in one variable either within suckler beef (a-d) and or within heifers (t-z) are significantly different at $P<0.05$, [2] *P*-value of contrast between suckler units and heifers, [3] only calves in the suckler units, [4] only cows in the suckler units

Table 3
Effect of experimental group (G), pasture type (P) and year (Y) on N conversion[1]
Einfluss der Versuchsgruppe (G), der Weide (P) und des Jahres (Y) auf den N-Umsatz

Category		Suckler cow & calf				Heifer						*P*-value					
Year/Pasture	Y	P1	P2	P3	Mean	P1	P2	P3	Mean	SEM	Contrast[2]	G	P	Y	G×P	G×Y	G×P×Y
N intake																	
g/d	A	268^{c}	312^{c}	494^{ab}	392	113^{z}	172^{xy}	271^{t}	191	13.6	<0.001	<0.001	<0.001	<0.001	<0.001	0.463	0.107
	B	307^{c}	428^{b}	540^{a}		133^{yz}	180^{x}	279^{t}									
g/kg BW and d	A	0.416^{c}	0.447^{c}	0.690^{a}	0.526	0.375^{yz}	0.493^{y}	0.752^{x}	0.509	0.015	0.331	0.013	<0.001	0.939	<0.001	0.257	0.211
	B	0.406^{c}	0.534^{b}	0.657^{a}		0.338^{z}	0.438^{yz}	0.662^{x}									
g/kg BW$^{0.75}$ and d	A	2.10^{c}	2.30^{c}	3.57^{a}	2.75	1.56^{yz}	2.13^{y}	3.28^{x}	2.24	0.082	<0.001	<0.001	<0.001	0.179	0.003	0.471	0.164
	B	2.13^{c}	2.84^{b}	3.51^{a}		1.51^{z}	1.97^{yz}	3.00^{x}									
N balance (% of N intake)																	
System N retention[3]	A	14.8^{a}	15.3^{a}	5.4^{b}	7.7	17.9^{y}	8.6^{z}	4.7^{z}	8.7	1.08	0.408	0.768	<0.001	<0.001	0.259	0.259	0.018
	B	4.5^{b}	3.0^{b}	4.9^{b}		7.2^{z}	7.4^{z}	5.5^{z}									
Faecal N	A	50.3^{a}	42.0^{b}	36.2^{bc}	40.1	45.7^{y}	40.4^{yz}	31.6^{yz}	38.1	1.17	0.144	0.429	<0.001	0.006	0.002	0.016	0.014
	B	40.2^{bc}	40.1^{bc}	34.5^{c}		44.9^{y}	39.3^{yz}	26.7^{z}									
Urinary N[3]	A	35.0^{b}	42.7^{b}	58.4^{a}	52.3	35.4^{z}	51.0^{xy}	63.8^{tx}	53.2	1.45	0.560	0.715	<0.001	<0.001	<0.001	0.014	0.002
	B	55.3^{a}	56.9^{a}	60.6^{a}		47.8^{yz}	53.3^{xy}	67.8^{t}									
Total N excretion[3]	A	85.3^{b}	84.7^{b}	94.6^{a}	92.3	82.1^{z}	91.4^{y}	95.3^{y}	91.3	1.08	0.408	0.768	<0.001	<0.001	0.259	0.259	0.018
	B	95.5^{a}	97.0^{a}	95.1^{a}		92.8^{y}	92.6^{y}	94.5^{y}									
Relative N excretion																	
Urinary N[3] (% of total N excretion)	A	40.1^{c}	50.2^{b}	61.7^{a}	56.1	44.0^{z}	55.9^{yz}	66.9^{xy}	58.0	1.41	0.247	0.513	<0.001	<0.001	0.002	0.021	0.004
	B	57.9^{ab}	58.6^{a}	63.7^{a}		52.0^{yz}	57.5^{xyz}	71.8^{x}									
Total N (g/kg weight gain[4])	A	200^{c}	221^{c}	435^{ab}	376	198	347	687	486	59.7	0.117	0.138	<0.001	0.004	0.423	0.434	0.055
	B	350^{bc}	512^{a}	536^{a}		800	425	466									

[1] LS Means carrying no common superscript in one variable either within suckler beef (a-c) and or within heifers (t-z) are significantly different at $P<0.05$, [2] *P*-value of contrast between suckler units and heifers, [3] estimated from N balance assuming ± 26 g N/kg body weight change (GIBB *et al.* 1992, ESTERMANN *et al.* 2003), [4] only calves in the suckler units

Table 4
Effect of experimental group (G), pasture type (P) and year (Y) on P turnover[1]
Einfluss der Versuchsgruppe (G), der Weide (P) und des Jahres (Y) auf den P-Umsatz

Category		Suckler cow & calf				Heifer						*P*-value					
Year/Pasture	Y	P1	P2	P3	Mean	P1	P2	P3	Mean	SEM	Contrast[2]	S	P	Y	G×P	G×Y	G×P×Y
P intake																	
g/d	A	44.5^{ab}	34.8^{c}	39.6^{bc}	43.7	19.8	19.0	19.9	20.3	1.30	<0.001	<0.001	<0.001	<0.001	0.007	0.233	0.083
	B	51.5^{a}	50.0^{a}	41.4^{bc}		21.4	21.4	20.1									
mg/kg BW and d	A	69.1^{a}	50.0^{c}	55.4^{bc}	59.3	65.5^{y}	54.5^{yz}	55.3^{yz}	54.9	1.60	0.023	0.002	<0.001	0.811	0.010	0.104	0.132
	B	67.6^{a}	62.5^{ab}	50.3^{c}		54.5^{yz}	51.9^{yz}	47.7^{z}									
mg/kg BW$^{0.75}$ and d	A	348^{a}	256^{c}	286^{bc}	308	273	235	241	240	8.3	<0.001	<0.001	<0.001	0.067	0.007	0.225	0.119
	B	355^{a}	332^{ab}	269^{c}		243	234	216									
Faecal P excretion																	
% of P intake	A	78.5^{ab}	65.0^{cd}	60.0^{d}	70.8	77.1^{x}	62.5^{yz}	57.7^{z}	74.5	1.27	0.017	<0.001	<0.001	<0.001	<0.001	<0.001	0.014
	B	86.0^{a}	65.2^{cd}	71.5^{bc}		99.0^{t}	74.8^{xy}	75.8^{xy}									
g/g weight gain[3]	A	29.3^{bc}	18.7^{d}	22.1^{cd}	32.0	21.3	26.3	29.9	46.7	7.54	0.098	0.278	0.008	0.004	0.610	0.460	0.144
	B	53.3^{a}	40.3^{b}	30.4^{cd}		134.9	40.3	27.5									

[1] LS Means carrying no common superscript in one variable either within suckler beef (a-d) and or within heifers (t-z) are significantly different at $P<0.05$, [2] *P*-value of contrast between suckler units and heifers, [3] only calves in the suckler units

The daily system N intake was twofold higher for the suckler units than for the heifers, but similar in both categories when related to BW and 1.2-fold higher when related to $BW^{0.75}$ (Table 3). Animals of both categories had higher absolute and relative N intakes on P2 compared to P1 and on P3 compared to P2 and P1 ($P<0.001$). The increase in N intake from P1 to P3 was relatively higher in the heifers compared to the suckler units. Faecal and estimated urinary N excretions, given as percentages of N intake, were not significantly different between livestock categories, but differed between pastures and years. In detail, when moving animals from P1 to P2 and P3, faecal N percentage and its proportion of total excretory N decreased. Total excretory N loss relative to intake was highest on P3. Across all pastures, a large difference was found in total N excretion between years A and B (89 vs. 95 % of N intake). The two measures of N efficiency, system body N retention relative to N intake and total N excretion per unit of BW gain, also showed only small differences between categories and highly significant effects of pastures and years. The few numerical differences between categories probably resulted from adding up of errors due to a high individual variation in these ratios.

P intake was higher (absolute and relative to $BW^{0.75}$) in the suckler units compared to the heifers (Table 4). In the suckler units, P intakes on P2 and P3 were lower than on P1 whereas in the heifers P intake remained constant across pastures. Faecal P loss, although being lower in absolute terms, was higher in the heifers compared to the suckler calves when related to BW gain.

Discussion

In the present study, intake and nutrient turnover on mountainous pastures of suckler cows grazing together with their progeny was compared with that of growing heifers, the latter being one of the most common livestock system options on higher altitude pastures. Concerning suckler beef, the experimental cows and their progeny overall presented a balanced mix of options concerning breeds, calving schedules, and calf gender. The central technique used was based on n-alkanes as markers for the estimation of total, N and P intake and nutrient digestibility of herbage. This technique has been successfully tested and applied in several other studies on mountainous pastures either with dairy cows or with suckler beef (e.g. MALOSSINI *et al.* 1994, BERRY *et al.* 2001, ESTERMANN *et al.* 2001, 2003, LEIBER *et al.* 2006, BOVOLENTA *et al.* 2008).

Selection, intake and digestibility of herbage

Animals of all categories showed only a weak inclination to select for or against higher nutrient contents of herbage, indicating that no energy- or nitrogen-driven dietary selection was necessary to cover requirements. This is different from situations where high-yielding animals are used or from situations where no rotational grazing is practiced (e.g. DUMONT *et al.* 2007). Differences in OM and NDF digestibilities of herbage between pastures and between years probably did not result from a different feed selection pattern but reflected typical variations due to vegetative stage and species proportion on the respective sites (SCHUBIGER *et al.* 1998). In general, digestibility levels were similar to those reported by BERRY *et al.* (2002) for both suckler cows and dairy cows grazing similar pastures.

Intakes of DM, N and P were astonishingly similar in suckler beef and heifers when adjusted for BW, while significant differences remained at the level of metabolic BW. The general decrease in variability of DMI by adjustment for BW and the small residual livestock system differences therefore suggest that BW is the major variable affecting herbage DMI (MERTENS 1987). As the ratio of total BW to BW gain was equal in both categories, a similar DMI could have been expected from that respect. However, maintenance requirements, representing a significant proportion of total energy needs, depend on metabolic BW rather than on BW. Therefore, in DMI no complete similarity should result when adjusting to BW. Variations may have been masked by system differences in feed conversion (direct transformation in heifers, and only after a second transformation of energy from grass to milk in the suckler units). The associated losses would explain the higher DMI required per unit of metabolic BW in the suckler units. Also intakes of NDF relative to BW did not differ between the suckler beef (1.12%) and the heifers (1.09%). These values were just around MERTENS' (1987) threshold value in NDF intake (1.1% of BW), a value which was found to be largely surpassed by dairy cows on alpine pastures (BERRY *et al.* 2001).

The DMI adjusted for BW differed between pastures by increasing from P1 to P2 and P3 in both categories. This was likely caused (i) by the increase in BW of the suckler calves and the heifers which had taken place in the meantime and (ii) by a higher energy demand on high altitude because of low oxygen pressure, unfavourable slopes and other constraints (COULON and PRADEL 1997). Pasture quality in terms of metabolisable energy was quite similar making this a less likely explanation although also preference for and aversion against plant species might have played a role. Data showed that the additional energy intake on the alpine site was equivalent to about 1.0-fold and 0.7-fold of the expected total lowland resting energy maintenance requirement (RAP 1999) for the suckler beef and the heifers, respectively. This is in the range reported for dairy cows exposed to the same high altitude area (BERRY *et al.* 2001, LEIBER *et al.* 2006).

Due to the similar DMI, when adjusted for BW, the potential stocking density (kg BW/hectare) was almost identical in both systems options. This density not only depends on feed consumption of the animals but also on herbage mass available. Accordingly, it decreased from P1 to P2 and, particularly, from P2 to P3 as the latter provided clearly less herbage than similar areas at their first use (P2) as reported earlier (CERNUSCA *et al.* 1997).

Animal performance

The average BW gains measured for suckler calves (1 056 g/d) and heifers (550 g/d) were within a typical range for these animal categories, when grazing of mountainous pastures is included (TROXLER and JANS 2000). In the study of LOSAND *et al.* (2007), gains of BW of previously intensively reared heifers were found to be clearly lower (about 300 g/d) when they were turned out to moor pasture, and there was compensatory gain after the grazing period. This suggests that the requirements of the heifers were covered better in the present study, although some kind of compensatory growth still might have occurred when returning from the mountainous pastures. Performance of the calves was not significantly influenced by the experimental period. This indicates that nutrient requirements of calves were widely covered on all pastures by milk and own forage nutrient intake (DRENNAN 1984) in the genotypes used. This is confirmed by the study of DRENNAN and MCGEE (2009), at least for lowland grazing conditions, where intensification and higher fertilisation of lowland pasture did not result in increased gains of suckler calves. Because the relative differences in forage DMI and BW gain were comparable, the two livestock categories expressed quite similar feed conversion efficiencies. There were significant differences in BW gains between years A and B in both system options, with the lowest weight gains occurring in year B on P1 (and P2). The relatively lower herbage quality on P1 in year B (obvious from metabolisable energy content and OM digestibility) probably contributed to that. Another factor might have been the heavy rainfall at that time adversely affecting DMI (MALOSSINI *et al.* 1995). Corresponding to the low BW gain of the offspring, suckler cows lost considerable amounts of weight (–348 g/d) in this period whereas in year A cows had gained 350 g/d on the same pasture.

Nitrogen and phosphorus conversion

The utilisation of ingested N was similar between livestock categories illustrating that the apparent advantage of suckler beef through the clearly higher growth rates of the calves is completely lost by the, in this sense, unproductive cows which on average more or less maintained their BW. The average level of N utilisation found corresponded well with the range of 5 to 10 % reported elsewhere for beef cattle (HOLMES 1970, ESTERMANN *et al.* 2001) and was higher than that found when using extensively growing suckler beef breeds (BERRY *et al.* 2002). In contrast, dairy cows grazing alpine pastures utilise N far better (ESTERMANN *et al.* 2001, BERRY *et al.* 2002). It is important to note that, independent from the livestock category, N utilisation greatly differed between pastures and years covering a range from 3 to 18 % of N intake. Intakes of protein (N), when exceeding requirements, result not only in higher total N losses but in a higher proportion of the easily volatile urine (BUSSINK 1994) which is especially detrimental on alpine pastures where excretion of the animals, which is patchy anyway, is often concentrated locally to a few places (JEWELL *et al.* 2007).

Phosphorus intake through herbage was not sufficient to completely cover estimated P requirements for growing (TERNOUTH *et al.* 1996) and lactating cattle (TERNOUTH and COATES 1997), indicating the need for P supplementation as it was also proposed earlier (SPATZ *et al.* 1981) from mineral compositional data of herbage growing on unfertilised alpine pastures. However, in the present study the additional P intake from the mineral mixture on average still only accounted for 10 % of total P intake, with an unknown variation in individual animals. This low P supply might explain why the estimated faecal P excretion only accounted for about 70 to 75 % of P intake, which is low considering that faeces are the predominant route of P excretion in cattle (WU *et al.* 2000) and suggest a high P utilisation for BW gain.

Conclusions

The present study showed that, different from expectations, suckler beef from intensively growing breeds and non-lactating dairy heifers grazing mountainous pastures achieve, in a system-based comparison, similar levels of feed conversion efficiency and relative N and P utilisation, in spite of grossly differing absolute growth performances. This implies that a similar stocking density (livestock units/hectare) is possible and that the same N amount is lost per hectare in the sensitive alpine environment with both categories, thus being equivalent choices in terms of N utilisation. The small remaining differences between categories appear to be negligible compared to the variations caused by pasture type and year. This needs to be tested under different stocking densities as livestock systems may differ in nutrient requirements and, consequently, in the minimum pasture quality needed. When heifers are considered as an essential component of dairy farming, this system option is superior in overall system nutrient use efficiency to suckler beef, taking into account the far higher efficiency of dairy cows (BERRY *et al.* 2002, ESTERMANN *et al.* 2003). In favour of the suckler system is, however, that it profits from the direct transfer of desired diet ingredients from grass to meat (COULON and PRIOLO 2002, RAZMINOWICZ *et al.* 2006), particularly those prevalent only in high altitude herbage (WILDI and LUTZ 1996), an advantage not feasible in heifers designed for milk production.

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